1979-05-01

Water Quality of the Upper Great Lakes: An IJC Report to the Governments of Canada and the United States

International Joint Commission

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WATER QUALITY OF THE UPPER GREAT LAKES

INTERNATIONAL JOINT COMMISSION

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MAY 1979

FIRST PRINTING (MAY 1979)

Report available from:

United States Section
International Joint Commission
1717 H Street, N.W.
Washington, D.C. 20440

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International Joint Commission
100 Metcalfe Street
Ottawa, Ontario K1P 5M1

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TABLE OF CONTENTS

CHAPTER	TITLE	PAGE

LIST OF TABLES

LIST OF FIGURES

1. SUMMARY

On April 15, 1972 the Governments of Canada and the United States requested the International Joint Commission to determine the extent and causes of pollution in Lakes Superior and Huron, identify practicable remedial measures, and recommend measures to prevent further degradation. These questions have been addressed and reported upon by the Commission's Upper Lakes Reference Group, and a series of public hearings on the Reference Group's findings have been held. The Commission's findings and recommendations are set out in this report.

The Commission finds that the overall water quality of the Upper Lakes is excellent, but there are many sources of pollution which should be reduced or eliminated if the existing high quality is to be maintained. The Commission also finds that transboundary pollution occurs in the St. Marys River as a result of the discharge of phenolic substances by the Algoma Steel Corporation and by the City of Sault Ste. Marie, Ontario.

Water use problems occur in several areas, particularly in Saginaw Bay on Lake Huron and Duluth-Superior Harbor on Lake Superior, as a result of inputs of nutrients, primarily phosphorus, and of organic substances. The nutrient inputs to Saginaw Bay are also degrading the open waters of southern Lake Huron. Bacteriological water quality degradation was found in many localized nearshore areas, with violations of the Great Lakes Water Quality Agreement objectives occurring at several locations. Violations of the Ontario criterion for radium in drinking water supplies continue to occur at Serpent Harbour on the North Channel. Water quality in the western arm of Lake Superior is adversely affected by asbestos inputs from Reserve Mining Company.

In the St. Marys River, the sediments are contaminated with phenolic substances, oil, cyanide, iron, and zinc, and the waters are contaminated with phenolic substances and cyanide, discharged from Algoma Steel Corp. Sediments, water, and fish in many other nearshore areas of both lakes also exhibit unacceptably high concentrations of heavy metals and toxic organic substances as a result of their discharge, both intentionally and inadvertantly, into the environment. Because of the nature of the use of some of these substances, it is difficult to prevent their unintentional escape. Further, because toxic organic substances are present in atmospheric and land runoff inputs as well as point source inputs, they also constitute whole-lake problems.

The Commission recommends that Governments implement regulatory and remedial measures to eliminate these problems and to restore water quality. The Commission also recommends those surveillance, monitoring, and research activities which are necessary to assure restoration and maintenance of water quality.

Notwithstanding these instances of pollution, the overall water quality of the main bodies of the Upper Lakes is much better than both the Agreement

objectives and the federal, state, and provincial standards. The Commission considers it imperative that the Upper Lakes be maintained at their present high quality if existing and future uses are to be maintained.

The Commission recognizes that this goal may be difficult to attain if economic growth and development are to be accommodated and if pollution control technology is limiting. The Commission recommends, therefore, that all existing activities and all planned or potential development that may lead to water quality degradation be subjected to an analysis that will ensure that degradation will be prevented. Proponents of development should be required to assure Governments, before they are given approval to proceed with such development, that degradation will not occur.

To avoid degradation, the Commission recommends that phosphorus concentrations in the effluents of municipal and industrial discharges, as well as the phosphorus content of detergents, be limited. The Commission also recommends a policy whereby phosphorus loadings will be maintained or reduced, while accommodating future growth, in order to ensure that the phosphorus loading to the Upper Lakes does not increase in the future and is reduced as much as practicable.

Inputs of several metals to certain areas have been identified as potentially harmful to human health, aquatic life, and the environment. The Commission recommends minimizing the discharge of these materials in these areas until their effects can be determined.

Persistent toxic organic substances represent an urgent problem because of their essentially irreversible effects. The Commission recommends banning the manufacture, import, and use of certain of these substances, including PCB's, PBB's, aldrin, dieldrin, DDT and its derivatives, and other persistent, highly toxic substances, whose entry into the environment is difficult to control, if their use is permitted. As for other such substances with known deleterious effects, the Commission recommends strict regulatory control to prevent entry into the environment. The Commission also recommends that the producers of new organic substances be required to demonstrate the safety of these substances before they are used, and the use of substances presently being produced, but whose safety is not yet known, should be restricted until such safety can be established. The Commission urges Governments to develop and adopt mutually acceptable or compatible methods of determining the persistence and toxicity of such compounds.

The Commission also recommends further efforts to determine clearly the extent of the health hazard posed by asbestos in drinking water so that appropriate standards and objectives can be established and appropriate controls implemented. Because of the possible harmful effects of asbestos on health, the Commission applauds the U.S. federal court decision that Reserve Mining cease discharging tailings into Lake Superior and recommends that steps be taken to minimize erosion from the tailings delta.

The Commission identifies for future action new concerns which have arisen from the study by the Reference Group. Their study indicates that atmospheric inputs may be responsible for up to 40% of the loadings of certain pollutants to the lakes, including phosphorus, heavy metals, toxic organic contaminants, and sulphur dioxide, which contributes to the acid rain phenomenon. The Commission recommends that the contribution of atmospheric inputs to Great

Lakes water quality degradation be addressed by the Governments on a scale broad enough to permit tracing of significant sources of these inputs to the lakes, especially as many of the sources may be located outside of the Basin.

The study has also shown that, if the goals of nondegradation and restoration are to be met, society must develop new and innovative technologies. These must eventually include resource conservation methods as well as new treatment processes. The Commission perceives the role of the Governments to be one of encouraging and coordinating development and implementation of these measures and of providing incentives toward this end. There are many initiatives available to Governments which they must employ if the objectives of the Great Lakes Water Quality Agreement are to be met and nondegradation achieved.

2. INTRODUCTION

HISTORICAL PERSPECTIVE

The Great Lakes represents the largest single system of fresh water in the world, amounting to approximately one quarter of the world supply of fresh surface water. Because of this vast supply and its availability as a unique transportation system, the Great Lakes provided a gathering point for a significant segment of the economies of both Canada and the United States. However, with man's continued encroachment and settlement in the Great Lakes Basin came increased use and eventual degradation of these waters from their original conditions.

As a result of the concerns about boundary waters, the Governments of the United States and Canada signed the Boundary Waters Treaty in 1909, under which the International Joint Commission was established. An essential provision of the Treaty is that neither country shall pollute the water to the injury of health or property of the other. One of the first references to the Commission under the Treaty came in 1912 and was prompted by the prevalence of typhoid fever arising from contaminated drinking water. The Commission reported in 1918 that "the situation along the frontier . . . is generally chaotic, everywhere perilous and in some cases disgraceful and very intense along the shores of the Detroit and Niagara Rivers." Sewage from cities and industries was found to be the major cause of pollution, with waste treatment the appropriate remedy. The report recommended that the Governments " . . . . confer upon the International Joint Commission ample jurisdiction to regulate and prohibit this pollution of boundary waters." The introduction of chlorination of drinking water, however, eliminated the threat of typhoid fever and postponed investment in waste treatment facilities. No action was therefore taken to implement the Commission's recommendations.

In 1946, the Commission was requested to enquire into the pollution problems of the connecting channels of the Great Lakes (the St. Marys, St. Clair, Detroit, and Niagara Rivers). In its 1950 report, the Commission recommended specific water quality objectives designed to restore and maintain these waters. These objectives were subsequently adopted in both countries and became an integral part of their pollution abatement programs. Construction of new and expanded waste treatment facilities improved the situation, but the addition of waste treatment facilities was late in coming and did not keep pace with the rapid population growth and industrial expansion.

Recognizing that water quality in the Great Lakes was continuing to deteriorate, the Governments in 1964 requested the Commission to investigate the condition of the Lower Lakes; report the extent, causes, and localities of pollution; and recommend remedial measures. In its 1970 report, the Commission recommended water quality objectives for Lake Ontario, Lake Erie, the international section of the St. Lawrence River, and their connecting channels. The report further urged that the Governments enter into agreement on programs and measures to achieve these objectives. Another recommendation was that the Governments study the remaining boundary waters - Lake Huron and Lake Superior. As a result, the Governments entered into the 1972 Great Lakes Water Quality Agreement and, at the same time, initiated a reference to study Lake Huron and Lake Superior and to identify pollution and degradation of those lakes.

The Governments indicated in their terms of reference (Appendix A) that since Lake Michigan is wholly within the United States, it should be considered only as a tributary to Lake Huron.

UPPER LAKES REFERENCE QUESTIONS

By letter of April 15, 1972, the Commission was requested to enquire into and to report upon the following questions:

1. Are the waters of Lake Superior and Lake Huron being polluted on either side of the boundary to an extent (a) which is causing or is likely to cause injury to health or property on the other side of the boundary; or (b) which is causing, or likely to cause, a degradation of existing levels of water quality in these two lakes or in downstream portions of the Great Lakes System?

2. If the foregoing questions are answered in the affirmative, to what extent, by what causes, and in what localities is such pollution taking place?

3. If the Commission should find that pollution of the character just referred to is taking place, what remedial measures would, in its judgement, be most practicable to restore and protect the quality of the waters, and what would be the probable cost?

4. In the event that the Commission should find that little or no pollution of the character referred to is taking place at the present time, what preventive measures would in its judgement, be most practicable to ensure that such pollution does not occur in the future and what would be the probable cost?

The complete text of the reference to the Commission is given in Appendix A.

THE UPPER LAKES REFERENCE GROUP

ORGANIZATION

The Commission appointed the Upper Lakes Reference Group in November 1972 to undertake the appropriate studies to answer these questions and to report its findings to the Commission, which would, in turn, report to the Governments.

The Reference Group was composed of fourteen scientists and engineers of various disciplines from the federal, state, and provincial governments. The Reference Group, in turn, organized a number of work groups to conduct the proposed studies, using the reference questions as a guide for developing a detailed study plan. The membership of the Reference Group and its work groups is given in Appendix B.

STUDY PLAN

The plan contained six study items:

Study Item I: Compile background information on the geological, hydrological, and climatological characteristics of the Upper Lakes and their basins; compile material on demographic and economic conditions and developments related to human activities; and consider the extent to which each influences water quality.

Study Item II: Survey the open waters of the Upper Lakes. The Reference Group sought information on both water quality conditions and lake processes which affect water quality and materials transport. The surveys were designed to establish baseline or reference levels of the constituents with which future water quality could be compared.

Study Item III: Investigate the sources and characteristics of the inputs of materials which could adversely affect the water quality of the Upper Lakes. This information was used to assess the need for remedial programs to reduce or prevent pollution.

Study Item IV: Investigate human, geographic, and water resource interrelationships, in order to better understand the influence of population, economic activities, technology, sociology, and policy legislation, and changes in these, on the water quality of the Upper Lakes.

Study Item V: Identify and describe pollution or degradation of nearshore waters, harbours, and embayments.

Study Item VI: Evaluate the data collected in the open water and sediment surveys. With a better understanding of present open water conditions and materials transport processes, the Reference Group could develop total-lake management alternatives.

COST AND TIME

Conduct of the study required 3½ years of concerted effort and the involvement of well over 200 persons from the scientific and academic communities. The total cost of the study was approximately 14 million dollars. The Reference Group presented Volume I of its report, Summary and Recommendations, to the Commission in July 1976. However, completion of the detailed reports on Lake Huron (Volume II) and Lake Superior (Volume III) required more than another year.

The Commission deferred completion of its report to Governments on the Upper Lakes study in order to present the Reference Group's findings and the Commission's recommendations to Governments in light of the findings and the recommendations of the companion study conducted by the Pollution from Land Use Activities Reference Group, which presented its report to the Commission in July 1978; and in consideration of the revised Great Lakes Water Quality Agreement, signed on November 22, 1978.

proposed studies; revising the reference questions as appropriate; developing a detailed study plan; and confirming membership of the Reference Group. Details of its composition are given in Appendix A.

STUDY PLAN

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Study Item I: Compile background information on the geological, hydrological, and climatological characteristics of the Upper Lakes and their basins; compile material on demographic and economic conditions and developments related to human activities; and consider the extent to which each influences water quality.

Study Item II: Survey the open waters of the Upper Lakes. The Reference Group sought information on both water quality conditions and lake processes which affect water quality and materials transport. The surveys were designed to establish a data base of present levels of the constituents with which future water quality could be compared.

Study Item III: Estimate the nature, magnitude, and characteristics of the inputs of materials which could adversely affect the water quality of the Upper Lakes. This information was used to assess the need for remedial programs to reduce or prevent problems.

Study Item IV: Investigate human, economic, and water resource interrelationships, in order to better understand the influence of population, economic activity, technology, public policy and legislation, and changes in these, on the water quality of the Upper Lakes.

Study Item V: Identify and describe pollution or degradation of nearshore waters, harbours, and embayments.

Study Item VI: Assess the data collected in the open water and sediment surveys in order to better understand present water conditions and materials transport processes. The Reference Group would develop total-lake management alternatives.

COST AND TIME

Completion of the study required 5 years of concentrated effort, and the involvement of well over 200 persons from the scientific and academic communities. The total cost of the study was approximately 14 million dollars. The Reference Group presented Volume I of its report, Summary and Recommendations, to the Commission in July 1976. However, completion of the detailed reports on Lake Huron (Volume II) and Lake Superior (Volume III) required more than another year.

The Commission further delayed its report to Governments on the Upper Lakes study in order to present the Reference Group's findings and the Commission's recommendations to Governments in light of the findings and the recommendations of the companion study conducted by the Pollution from Land Use Activities Reference Group, which presented its report to the Commission in July 1978, and the negotiation of the revised Great Lakes Water Quality Agreement signed on November 22, 1978.

3. CHARACTERISTICS OF THE UPPER LAKES AND ITS BASIN

The major contributions of the Reference Group were to characterize the waters of the Upper Lakes and to describe man's impacts on these waters. Their study also provided new insights into the dynamics and the factors affecting the Lake Huron and Lake Superior systems. Exemplifying these insights are the accumulation and magnification of contaminants in the aquatic life of the lakes, the complexity of lake circulation patterns and materials dispersion, and the importance of atmospheric inputs. The study provides a reference point against which the effects of future population growth and technological development can be measured. The detailed descriptions of the social and economic, physical, and limnological characteristics of the Upper Lakes are given in the three-volume report of the Reference Group. The major findings are presented in this chapter.

DEMOGRAPHIC CHARACTERISTICS

The population of the Lake Superior and the Lake Huron Basins numbered 2,800,000 in 1970 and is projected to increase to 4,300,000 by the year 2020. Almost the entire increase will occur in the Lake Huron Basin.

Most of the population of the Lake Superior Basin, which totalled 686,000 in 1970, is concentrated around the western end of the lake in and around the cities of Duluth, Minnesota and Superior, Wisconsin (combined 1970 population of about 140,000), and in Thunder Bay, Ontario (1971 population of about 112,000). The present basin population is expected to increase only marginally, reaching 712,000 by 2020.

The 1970 Lake Huron Basin population of 2,200,000 is projected to increase by about 64% to 3,600,000 by 2020 and will be evenly divided between Canada and the United States. Major population concentrations in the United States are in the Saginaw River Basin, including the cities of Flint, Bay City, and Saginaw; and on the Canadian side in the Sudbury area. The three U.S. cities contain more than two-thirds of the population on the U.S. side of the basin; Sudbury comprises about one-sixth of the Canadian total.

Major economic activities in the Lake Superior Basin relate to wood, pulp, and paper production; mineral extraction (iron, copper, and nickel); and recreation (hunting, fishing, and skiing).

The major economic activities of the Lake Huron Basin relate to agriculture, mineral extraction and refining, and the production of consumer and durable goods. Recreation is also economically important. Since World War II, the eastern Georgian Bay area has rapidly evolved as the "cottage country" of Ontario. Here the transient summer population exceeds the permanent population.

Forests cover more than 90% of the Lake Superior Basin and the northern part of the Lake Huron Basin. Crop and pasture land account for about two-thirds of the land use in the southern portion of the Lake Huron Basin. The quality of runoff water from forested lands is usually higher than that from agricultural lands.

Lake Superior is used as a source of potable water by 19 communities and Lake Huron by 39 communities. The largest municipal users of Lake Superior water are Thunder Bay and Duluth. The largest municipal users of Lake Huron water are Saginaw, Bay City, Midland, and Port Huron, Michigan; and London, Sarnia, and Sault Ste. Marie, Ontario. Present and projected withdrawals from the lakes are summarized in Table 1.

Municipal wastewater is discharged to both the Upper Lakes and their basins. In the Lake Superior Basin, sewered communities represent 53% of the total basin population and 85% of the total urban population; in the Lake Huron Basin they represent 49% and 85%, respectively.

The major industrial water uses in the Lake Superior and the Lake Huron Basins include pulp and paper, mining, manufacturing, and thermal electric power generation. The quantities of water used are summarized in Table 2. Industrial water use is projected to increase significantly, but a number of factors, including technological improvements in processes and the application of closed systems, could decrease water use considerably.

PHYSICAL LIMNOLOGY

The major basin characteristics of the Upper Lakes are summarized in Table 3.

An understanding of the physical properties of the Upper Lakes is essential in determining the movement, residence time, rate of dispersion, and fate of materials discharged into the lakes, and therefore the impact of these materials on water quality. For example, because both Lakes Superior and Huron have long residence and flushing times but relatively short mixing times (3 years for Lake Superior), the input of persistent materials, such as PCB's, rapidly results in a long-term whole-lake problem.

The principal components of physical limnology are the water budget, thermal regime, and circulation.

WATER BUDGET

The sources of water to a lake and the time that the water remains in the lake are major factors in determining the impact on and the fate of materials discharged into it. Land drainage and direct precipitation into the lake make up all of the inputs to Lake Superior and about 45% of the inputs to Lake Huron, Georgian Bay, and the North Channel. Flows through the St. Marys River and the Straits of Mackinac comprise the remaining inputs to Lake Huron.

The net flow of water through the Straits of Mackinac is from Lake Michigan to Lake Huron. However, the exchange of water between the two lakes oscillates and is extremely complex, with the total volume transported in either direction being up to 40 times the net flow. In the exchange between Georgian Bay and Lake Huron, surface water is usually directed towards Georgian Bay and the deeper hypolimnion water to Lake Huron; seiches and long surface waves accelerate mixing between the water bodies and result in

TABLE 1

WATER WITHDRAWALS FROM THE UPPER LAKES
(cubic metres per day)

LAKE	MUNICIPAL 1970	MUNICIPAL 2020	INDUSTRIAL[b] 1976
SUPERIOR			
Canada	72,000	84,000	1,440,000
United States	91,000	218,000	4,620,000
HURON			
Canada	232,000	340,000	3,668,000
United States	254,000[a]	1,090,000[a]	5,140,000

a. Excludes a Detroit water supply intake located in Lake Huron and which has the capability to withdraw up to 1,510,000 m^3/d. The present Detroit withdrawal is about 5% of capacity and will not be increased significantly in the near future.

b. The magnitude of future industrial withdrawals will depend in part upon technological change and application of closed systems. Projected withdrawals are therefore not presented here.

TABLE 2

INDUSTRIAL USES OF UPPER LAKES WATER IN 1976

INDUSTRIAL CATEGORY	WATER USE, IN CUBIC METRES PER DAY: LAKE SUPERIOR Canada	LAKE SUPERIOR U.S.	LAKE HURON Canada	LAKE HURON U.S.
Pulp and Paper	723,000	-	230,000	-
Mining	53,000	2,165,000	522,000	62,800
Manufacturing and Miscellaneous	122,000	503,400	656,000	2,240,000
Thermal Electric Power	546,000	1,953,000	2,260,000	2,840,000
TOTAL	1,444,000	4,621,400	3,668,000	5,142,800

TABLE 3

CHARACTERISTICS OF THE UPPER LAKES

	LAKE SUPERIOR	LAKE HURON (TOTAL)	GEORGIAN BAY	NORTH CHANNEL
Lake Surface Area, km^2	82,103	59,570	15,108	3,950
Volume, km^3	11,920	3,539	660	88
Drainage Basin Land Area, km^2	127,687	131,313	45,893	34,250
Elevation, m	183	176	176	176
Mean Depth, m	145	59	44	22
Maximum Depth, m	406	229	165	84

TABLE 4

RESIDENCE AND FLUSHING TIMES[a]

LAKE	RESIDENCE TIME (YEARS)	FLUSHING TIME (YEARS)
Lake Huron (Whole Lake)	14	17
Lake Huron (Main Body	9	14
Georgian Bay	7	8
North Channel	2	2
Lake Superior	113	177

a. Based on gross flows through the connecting channels.

flushing and residence times shorter than would be indicated by net flows. The exchange of water in both directions through the Straits of Mackinac and in the channel between Lake Huron and Georgian Bay also results in the exchange of constituents in both directions.

The residence time of water in a lake is the volume of the lake divided by total inputs; the flushing time is the volume divided by the outflow. Values for the Upper Lakes are summarized in Table 4. The longer the residence and the flushing times, the longer the time required for a lake to recover from the input of a contaminant. If the annual rate of input of a persistent non-degradable material is greater than its rate of removal, that material will accumulate in the lake. For example, the 177-year flushing time for Lake Superior means that only about 0.56% of a nondegrading, nonsettleable, non-evaporating contaminant is removed each year through the St. Marys River. It is calculated that about 500 years is required for 95% recovery from the loading.

THERMAL REGIME

The thermal regime is important when considering the extent of dispersion of materials discharged to the lakes. The cyclic annual variation in the distribution of water temperature and density, temperature and heat transfer, thermal bars, upwellings and sinkings, and density currents all affect the dispersion and mixing of materials.

Vertical mixing in the offshore waters is limited mainly to the spring and fall overturns. At other times the development of a horizontal temperature gradient or thermocline effectively stratifies the water and inhibits vertical mixing between the epilimnion (top layer of water) and the hypolimnion (bottom layer).

Heat transfer affects current speeds and thus the rate of dispersion of materials. Epilimnion current speeds increase as the surface water temperature increases while hypolimnion current speeds remain more constant because heat and momentum transport are inhibited by the thermocline.

Thermal bars, which generally occur in the spring and early summer, separate warmer nearshore water from the cooler and denser offshore water. Thus, a thermal bar tends to confine materials entering a nearshore area and temporarily intensifies water quality degradation in the embayment.

An upwelling occurs when surface water is moved away by wind-induced currents, permitting cold hypolimnion water to move to the surface. Upwellings are common along windward shores, particularly along the northwest shore of Lake Superior. Hypolimnion water is usually richer in nutrients than the displaced surface water and therefore alters the temperature and chemical characteristics of the water of the coastal zones in a complex manner.

CIRCULATION

Although water circulation is caused primarily by wind and by differences in the density of the water, other contributing factors include currents from tributary inputs, inflow through major channels, precipitation, waves, variations in atmospheric pressure, upwellings and sinkings, and spring and fall overturns.

The general circulation patterns of Lakes Superior and Huron (Figures 1 and 2, respectively) are characterized by shore-parallel counterclockwise circulation. Perturbations such as storms can temporarily interrupt this pattern.

Saginaw Bay, the most important embayment of Lake Huron as a source of material input, has circulation patterns which are extremely dependent on a number of factors, including circulation of Lake Huron, bay geometry, wind speed and direction, flow from the Saginaw River, ice cover, and a thermal bar. Their relative importance varies according to a number of factors. With a prevailing southwesterly wind, water flows from Lake Huron to the inner bay through the deep channel on the north side of the Bay, past the mouth of the Saginaw River and out to Lake Huron along the south shore of the Bay (Figure 3). Much of the water entering Saginaw Bay from Lake Huron "short circuits" before flushing the inner bay; thus, the residence time of water in the inner bay (four months) is double the residence time of the Bay as a whole. The southwest corner of the inner bay, being nearly stagnant, has a longer residence time. Both ice cover in winter, and a thermal bar across the mouth of Saginaw Bay in the spring, inhibit water movement and allow for contaminant accumulation, especially in the inner bay. However, other factors offset these conditions to some extent. The thermal bar dissipates as the water temperature increases, and water movement and dispersion increase; by June, Saginaw Bay is almost completely flushed out due to storms and high spring flows from the Saginaw River.

SEDIMENT CHARACTERISTICS

The distribution and composition of sediments provide an indication of the source, dispersal, and fate of nutrients, heavy metals, and toxic organics. Sediments are related to the post-glacial evolution of the basins, generally reflecting the natural characteristics of the local bedrock geology. Comparison of the composition of recent sediments with older, deeper sediments allows identification of those materials caused by man's activities in the Upper Lakes Basin. The uptake of heavy metals and toxic organics from the sediments by benthic organisms can contribute to contaminant problems in fish.

Chemistry measurements for organic carbon and of the oxidation potential of the sediments confirm the oligotrophic ("healthy") nature of Lake Superior. More recently deposited sediments are higher in phosphorus, which indicates that the sediments are an effective "sink" for phosphorus inputs.

Similar measurements in Lake Huron sediments indicate that the southern sectors of both Lake Huron and Georgian Bay have suffered a decline in water quality due to increasing lake productivity. These southern basins show lower oxidation potentials and increased organic matter, contrary to what would be expected from the textural properties of the sediments of the southern basins. In addition, higher levels of total phosphorus were observed in the southern basin sediments of Lake Huron, likely due to enrichment caused by man.

The concentrations of trace metals in the sediments of the Upper Lakes are generally higher in the depositional basins than in the non-depositional zones. This implies that metals are usually associated with the finer sediments. Lead, cobalt, cadmium, and strontium levels are similar in the sediments of Lake Superior, Lake Huron, and Georgian Bay. Lake Superior

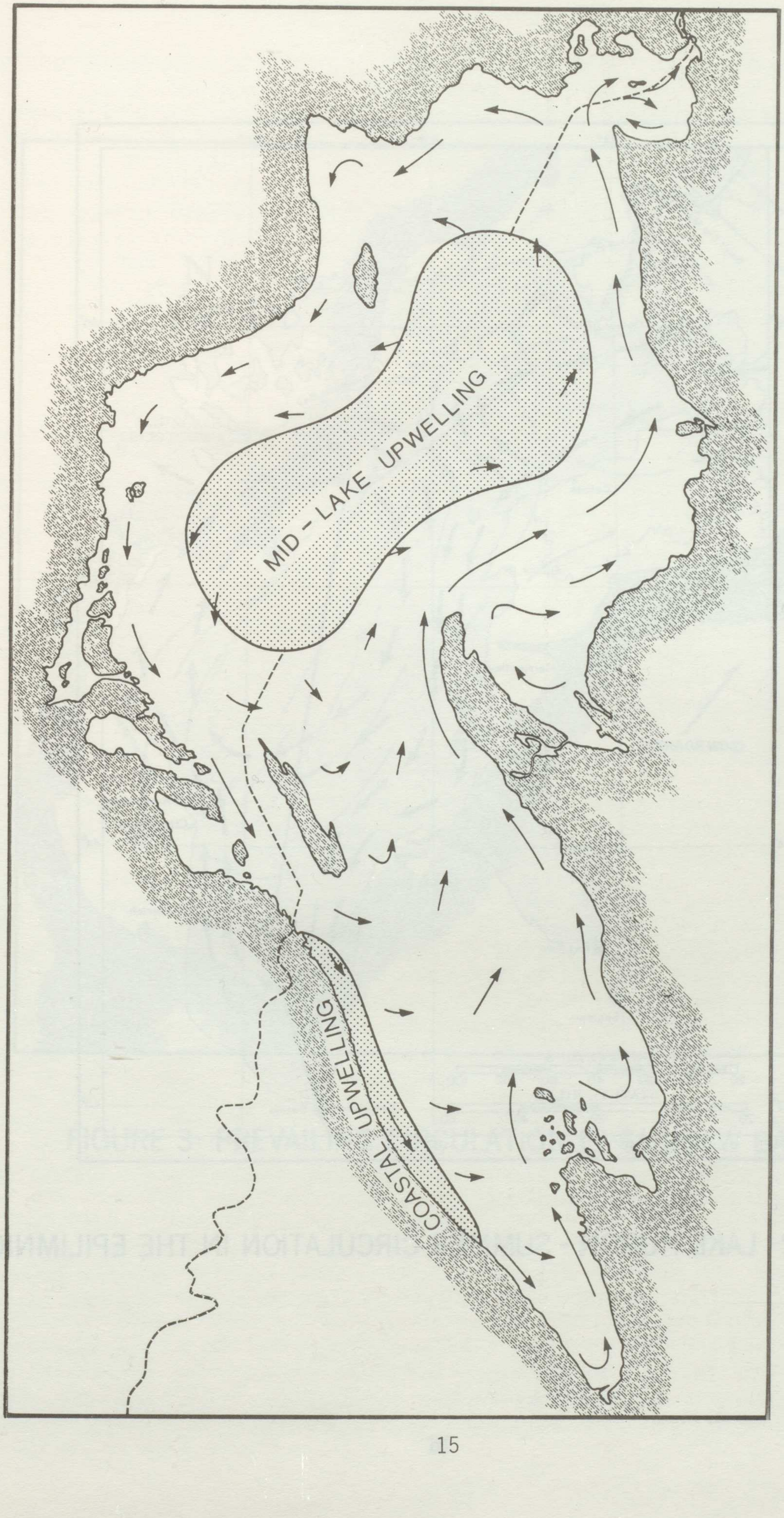

FIGURE 1 - LAKE SUPERIOR - SUMMER SURFACE CURRENTS

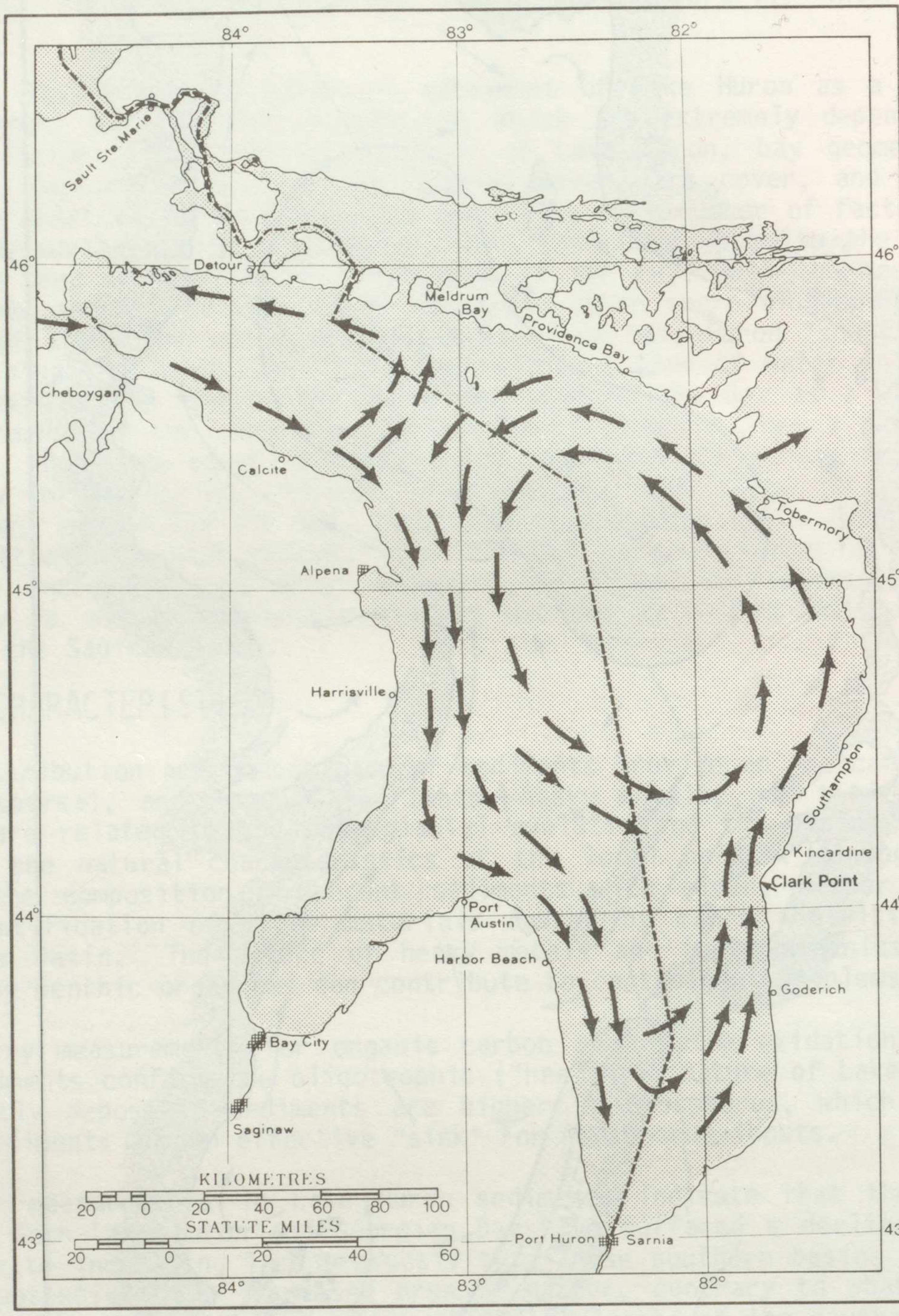

FIGURE 2- LAKE HURON - SUMMER CIRCULATION IN THE EPILIMNION

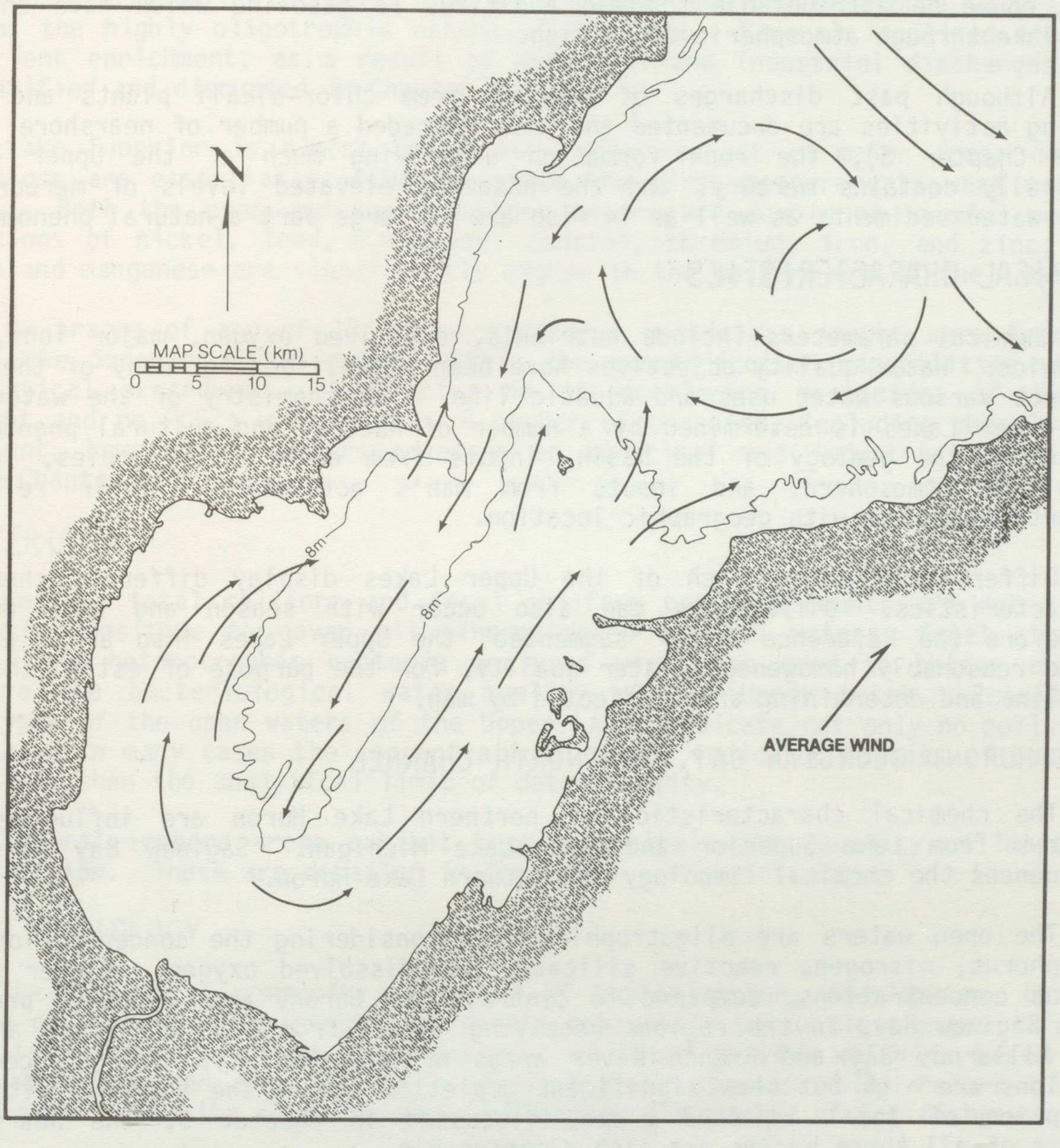

FIGURE 3 - PREVAILING CIRCULATION IN SAGINAW BAY

sediments have a higher content of copper, zinc, nickel, chromium, and vanadium. These differences are, in general, natural. However, elevated levels of lead occur in some open water sediments; the Reference Group indicated that this could be attributable to lead additives to gasoline which have entered the lake through atmospheric deposition.

Although past discharges of mercury from chlor-alkali plants and from mining activities are documented and have degraded a number of nearshore areas (see Chapter 5), the rock formation underlying much of the Upper Lakes naturally contains mercury, and the observed elevated levels of mercury in open-water sediments as well as in fish are in large part a natural phenomenon.

CHEMICAL CHARACTERISTICS

Chemical parameters include nutrients, dissolved oxygen, major ions, and organics. Water quality objectives have been established for many of these to protect various water uses and aquatic life. The chemistry of the waters of the Upper Lakes is determined by a number of natural and cultural phenomena, including the geology of the basin, inputs from other water bodies, inputs from the atmosphere, and inputs from man's activities. Their relative importance varies with geographic location.

Different areas of each of the Upper Lakes display different chemical characteristics. Differences can also occur with season and with depth. Therefore the Reference Group "segmented" the Upper Lakes into areas exhibiting reasonably homogeneous water quality, for the purpose of establishing a baseline and determining areas affected by man.

LAKE HURON, GEORGIAN BAY, AND NORTH CHANNEL

The chemical characteristics of northern Lake Huron are influenced by inflows from Lake Superior and from Lake Michigan. Saginaw Bay strongly influences the chemical limnology of southern Lake Huron.

The open waters are oligotrophic, when considering the concentrations of phosphorus, nitrogen, reactive silicate, and dissolved oxygen. Higher phosphorus concentrations, compared to central Lake Huron, are, however, present near Saginaw Bay, in the regions receiving inputs from Lake Michigan, and in the Killarney Bay and French River areas of Georgian Bay. Nitrate concentrations are high but show significant depletion during the summer. With the exception of local impacted areas, discussed in Chapter 5, the nearshore waters of all three basins are also oligotrophic.

The observed concentrations of major ions (calcium, magnesium, sodium, potassium, alkalinity, chloride, and sulphate) in the open waters of Lake Huron are typical of water of excellent quality. Nearshore water quality is similar to open water water quality.

Nickel, lead, manganese, cadmium, chromium, iron, and zinc concentrations in water are uniform and below harmful levels; high concentrations of copper have occasionally been found in central Lake Huron for no known reason.

Organics, including PCB's and organochlorine and organophosphorus pesticides, are largely non-detectable in the open water column, although phenolic substances and some chlorinated hydrocarbons have been detected in some nearshore waters receiving municipal and industrial discharges (see Chapter 5).

LAKE SUPERIOR

The chemistry of Lake Superior is dominated by natural inputs. The present low concentration of nutrients both in the open and the nearshore waters confirms the highly oligotrophic nature of the lake. Several localized areas of nutrient enrichment, as a result of municipal and industrial discharges, are identified and discussed in Chapter 5.

Lake Superior is almost homogeneous with respect to major ions; concentrations are essentially unchanged since the first measurements were made in 1885. Both the open and the nearshore waters are devoid of harmful concentrations of nickel, lead, manganese, cadmium, chromium, iron, and zinc; only iron and manganese are significantly higher in the western arm of the lake.

No traces of any of 15 organophosphorus pesticides sought were found in the Lake Superior water column within the quantification capabilities of the analytical procedures. Similarly, no organochlorine pesticides of the 17 sought and no PCB's were found. A number of organics, including phenols, are present, however, in waters adjacent to municipal and industrial discharges (see Chapter 5).

BACTERIOLOGY

Because total coliform and fecal coliform bacteria counts are not sufficiently sensitive to cover all circumstances and all waters, fecal streptococci and heterotrophic bacteria analyses were also used to better characterize the bacteriological water quality of the Upper Lakes. Results of analyses of the open waters of the Upper Lakes indicate not only no pollution, but also in many cases the concentrations of the indicator species of bacteria are less than the analytical limit of detectability.

Several inshore areas exhibit bacteriological water quality pollution or degradation. These are detailed in Chapter 5.

AQUATIC BIOLOGY

The biological community, composed of phytoplankton, zooplankton, benthic flora and fauna, and macrophytes, reacts measurably to subtle changes in water quality, thereby producing an assessment of water quality which is based upon the abundance and the diversity of biological species. The nature of the biological community also, in part, determines the health of the fishery.

The phytoplankton composition in the open waters of Lake Huron proper is similar to what might be expected in a large oligotrophic system in the early state of stress. Zooplankton and benthic flora and fauna also indicate oligotrophic conditions. However, some nearshore areas, particularly Saginaw Bay, are stressed and have a heavily impacted biota with blue-green algae predominating. Observed values of chlorophyll α, an indicator of the total amount of algae present in a body of water, were highest in Lake Huron north and south of Saginaw Bay.

Phytoplankton, zooplankton, and benthic populations in the open waters of Georgian Bay indicate oligotrophic conditions. Nearshore waters are also characterized by oligotrophic plankton types except in local areas such as Midland Bay and Penetang Bay where conditions are well into the mesotrophic range. The North Channel biological communities are similar to those in the open waters of Lake Huron.

Biological communities of the open waters of Lake Superior indicate an oligotrophic lake. Nearshore waters differ slightly; however, populations are low enough in all areas to indicate oligotrophic conditions. Only localized embayments like Duluth-Superior Harbor show signs of stress due to enrichment; both zooplankton and benthos of Duluth-Superior Harbor have species indicative of eutrophic conditions (see Chapter 5).

FISHERIES

Historically, both Lakes Huron and Superior were characterized by native fish communities typical of oligotrophic lakes. In both lakes the original fish stocks have been very substantially depleted. Long continued intense exploitation by man, coupled with the destabilizing influence of strong competition and predation by such exotic species as the alewife, rainbow smelt, and sea lamprey have played a major role in depleting the stocks. The extent to which deteriorating water quality has contributed to the depletion of native fish stocks is unknown.

Levels of contaminants in fish help determine the acceptability of the fish for human consumption. The levels also serve as another indicator of the overall water quality of the Upper Lakes, because persistent toxic organics and mercury bioaccumulate in fish tissue. In many cases, contaminants are found in fish even though they cannot be detected in the water column.

Contaminants found in fish taken from the open waters of Lake Superior include mercury, PCB's, DDT and its derivatives, dieldrin, and other chlorinated organics. The concentration of mercury in large, whole lake trout taken from several open-water locations were in excess of the health-protection guideline adopted by both countries. No other trace metals pose a recognized risk to human health. The concentration of PCB's in whole lake trout taken from the open waters approaches or exceeds the existing Canadian and the proposed U.S. guideline of 2 mg/kg, but does not exceed the existing U.S. guideline of 5 mg/kg. Mean levels of PCB's in skinless fillets of one subspecies, fat lake trout, caught at several nearshore locations, however, do exceed the 5 mg/kg guideline (see Chapter 5). Although concentrations of total DDT in whole lake trout were high, a substantial fraction of DDT and its derivatives is removed when the trout is dressed for sale so that the edible portions do not violate the U.S. and Canadian guideline. Similarly, dieldrin, though exceeding the U.S. and Canadian guideline in whole lake trout, did not exceed the guideline in edible portions.

The levels of contaminants in fish taken from the open waters of Lake Huron are similar to those in fish from the open waters of Lake Superior. PCB levels in whole fish taken from the open waters of northwestern Lake Huron approach or exceed the 2 mg/kg guideline, suggesting a possible relationship with the high PCB levels observed in Lake Michigan. In addition, concentrations of mercury and PCB's in samples of chinook salmon, rainbow trout, walleye, and northern pike taken from nearshore waters occasionally approach or exceed human health guidelines.

The presence of many other exotic organic compounds in fish indicates that the Upper Lakes ecosystem has been and continues to be degraded. Moreover, even at low concentrations, many persistent synthetic chlorinated organic contaminants are known to have chronic, sublethal effects on the fish and on man as a consumer of that fish (see Chapter 5). However, while the levels disclosed in the Reference Group's study (1974-75) were generally lower than those levels at which adverse effects have been conclusively determined, scientific assessment to determine adverse effects at low levels is ongoing. Thus, the presently established levels of safety, as reflected in the Water Quality Agreement objectives, should be continually reviewed.

Point sources to account for the observed concentrations cannot be identified because of mixing and dispersal mechanisms within the lakes. In addition, nonpoint inputs (atmosphere and land runoff) are significant contributors to the total input to the Upper Lakes. However, some probable point sources for some specific contaminants are discussed in Chapter 5.

4. WORKSHOPS AND PUBLIC HEARINGS

Upon receipt of the reference to characterize the Upper Lakes and identify pollution and degradation problems, the Commission held five initial hearings in 1972 and 1973 in order to invite the public to present its views prior to the start of the field investigations by the Reference Group.

Following completion of the study, the Reference Group presented its findings and recommendations to the Commission at its 1976 Annual Meeting on the Great Lakes Water Quality Agreement, held in Windsor, Ontario. In order to bring the findings of the study clearly to the attention of the public and to receive a more critical assessment of this material, the Commission then held six public education and information workshops before holding its final hearings. It entered into a contract with a non-profit United States-Canadian public awareness and participation organization to hold three workshops in each country to explain the contents of the Reference Group's report and its recommendations and to inform the public about the Commission's hearing process and how effective input to the hearings could be made. Public hearings on the Reference Group's report were then held in 1977 at six locations in the Basin.

All interested parties were invited to express their views and present documentary evidence at the hearings. The Commission also accepted written submissions following the public hearings. Statements were made by elected representatives, private individuals, citizens' groups, business and industrial representatives, and officials from federal, state, provincial, and municipal agencies. The names of those persons who gave testimony at the hearings are listed in Appendix C.

Verbatim transcripts of all hearings and copies of all written statements are available at the Commission offices in Ottawa and Washington, D.C., and at the Commission's Regional Office in Windsor, Ontario.

The Commission has reviewed the testimony given at the public hearings and all written submissions at or following the hearings.

INITIAL HEARINGS

The initial public hearings for the study of the Upper Lakes were held at Thunder Bay, Ontario, December 5, 1972; Duluth, Minnesota, December 7, 1972; Bay City, Michigan, January 8, 1973; Sault Ste. Marie, Ontario, January 22, 1973; and London, Ontario, January 24, 1973. Some comments directed toward the Upper Lakes study were also received at a hearing on Pollution from Land Use Activities at Toronto, Ontario, January 25, 1973.

In general, witnesses were concerned with local pollution problems and the effect of pollution on local water quality. Many witnesses were concerned particularly with the discharge from the Reserve Mining Company. The testimony presented to the Commission at the initial hearings is summarized below.

Many witnesses at the initial hearings were concerned with particular problems identified for specific geographic areas, such as poor quality drinking water at Thunder Bay and turbidity in Saginaw Bay. These areas, as well as Sault Ste. Marie and the Reserve Mining Company, were identified by government officials as being problem areas. The need for municipal sewage treatment plants was seen as immediate, and municipal, state, and provincial officials suggested that senior levels of government should provide adequate funding.

Urban growth was thought to add to pollution problems, and it was stated that urban growth should be balanced with the growth of waste treatment facilities.

As indicated above, a major public concern was the potentially harmful effects of the discharge of taconite tailings into Lake Superior from the Reserve Mining Company at Silver Bay, Minnesota. Some witnesses urged that the discharge from Reserve Mining should be halted immediately. One witness was concerned that the tailings contained asbestiform fibres, which might cause cancer when ingested. Other witnesses believed that the discharge had no effect on water quality, and that this had been shown by previous studies. Most witnesses, however, believed that the discharge warranted careful investigation in the study.

Testimony was received at the hearings concerning the economic impacts of pollution control. The Commission was told that Governments should aid industry in the costs of pollution control. Representatives of industry stated that the installation of waste recovery systems was not economical, and that more incentives were required. Current allowable write-offs were not thought to be high enough, and it was suggested that the Commission examine subsidies and incentives other than those for municipalities.

Other groups were concerned that the high costs of pollution control might be used as an economic weapon by industry. The Commission was told that, in some cases, workers were being forced to choose between the environment and their jobs. There was concern for the economic and personal effects of industry closing down because of pollution control requirements.

Regarding water quality standards, one witness stated that there should be mandatory compliance with pollution abatement laws by municipalities and industry, but it was noted that pollution abatement should be carried out without the creation of economic disparities. It was suggested that water quality standards should be set for areas where pollutants entered the lakes, thereby maintaining an overall high standard of water quality. Another witness stated that known sources of pollution should be eliminated immediately and there should be no further pollution of Lake Superior. It was suggested that the Commission urge Governments to impose environmental standards on proposed development projects for the Upper Lakes. Ambient water quality standards were not seen as providing as direct an enforcement tool as would effluent standards. One official observed that Ontario had water quality criteria, but had no philosophy of nondegradation. Problems caused by different methods of control in Canada and the U.S. were noted.

With respect to the general approach of the study, it was stated that basic research was needed regarding Lake Superior. Continuous monitoring of the lakes was thought to be required in order to better identify problem areas and to assist in finding solutions to problems. Another suggestion was that the Commission should concentrate its efforts on reducing the causes of pollution rather than remedying the effects.

Another issue that received much comment at the hearings was pollution from vessel wastes. It was generally thought that stricter controls were needed, and it was suggested that the problem might be controlled by the use of wastewater holding tanks on all vessels. Several municipal officials identified vessel wastes as a pollution problem and stated their desire for stricter regulations. One stated that Lake Superior might be designated a no-discharge zone.

Several witnesses were concerned with the potential effects of nuclear power plants on the Upper Lakes and specifically noted the problem of thermal pollution. It was stated that power plants should not be built on the lakes, and proposed plants should be relocated. It was suggested that more research be done into the effects of thermal pollution. One witness hoped that the Commission would recommend cooling standards for waste heat discharges from thermal generating plants.

The Commission was told that more public information was necessary and that a government education program would help in promoting individual awareness. It was believed that local awareness of pollution problems was not as great as it should be.

FINAL HEARINGS

The final round of public hearings was held at Superior, Wisconsin, June 20 and 21, 1977; Thunder Bay, Ontario, June 22, 1977; Houghton, Michigan, June 23, 1977; Sault Ste. Marie, Ontario, July 12, 1977; Collingwood, Ontario, July 13, 1977; and Saginaw, Michigan, July 14, 1977.

Most of the witnesses who testified told the Commission that the Reference Group had carried out an excellent study and that they agreed with the majority of the Group's recommendations.

Several witnesses made comments concerning the methodology of the Reference Group's study. It was stated that there were insufficient data, as there were no baseline values for water quality. One witness questioned the analytical techniques used for measuring contaminants in fish. There was concern expressed that not enough was presently known about the effects of asbestos fibres. It was also stated that more work needed to be done regarding the atmospheric input of metals into the lakes. It was noted that standardization was required for definitions regarding asbestos, for sampling methods, and for determining parameters for water quality objectives. One witness was concerned because the effect of air pollutants on water quality had not been emphasized, and that air standards should also be developed to protect water quality.

Regarding the general approach of the study and potential recommendations, several witnesses expressed the opinion that a macroenvironmental perspective was needed, and that a basin-wide, or overall ecosystem approach should be used. One governmental witness expressed the belief that there should be harmonious use of fisheries resources with aquatic and terrestrial ecosystems. Another witness stated that the Reference Group's recommendations should reflect a greater degree of political reality. Another stated that financial cost estimates should be associated with the recommendations. There were several comments to the effect that there should be a continuing evaluation of objectives and an ongoing review of standards and of governmental action.

There were many comments regarding potential water quality standards. It was stated that standards for Lake Superior should consider the effects on future industry. Concern was expressed by a municipal official that controls considered appropriate for large urban and industrial centres could affect the alternatives for growth and development of smaller centres. Comments by industry representatives were that standards should be flexible but still maintain the integrity of the natural resources, and that reasonable control technology might be taken into account, as opposed to zero discharge. In general, it was felt that controls and standards should be implemented in a flexible system.

Many witnesses stated their support for a policy of nondegradation in order to maintain the present high quality of the waters of the Upper Lakes. One witness was not completely supportive of nondegradation since he believed there was a lack of evidence to indicate the implications of the current levels of discharge into the Upper Lakes. A representative of industry was opposed to a nondegradation policy, as he believed such a policy would inhibit the attainment of other social and economic goals of equal priority. One witness criticized what he saw as a philosophy of trying to improve discharges into the lakes rather than trying to eliminate them. Another witness stated that all dumping into the lakes should be eliminated.

Representatives of the soap and detergent industry expressed concern with the Reference Group's recommendation regarding the reduction of phosphorus inputs to the Upper Lakes by banning phosphorus from detergents. They stated that implementation of that recommendation would not significantly improve the quality of the water in the Upper Lakes and would put hardships on the public. They also stated that the most effective means of reducing phosphorus inputs to the lakes would be at the waste treatment plants. Chemical removal of phosphorus at these plants was said to be sufficient at present to meet current standards.

A large number of environmental associations expressed concern over the atmospheric inputs of toxic materials into the Upper Lakes. Particular concern was expressed regarding the proposed power generating plant at Atikokan, Ontario and the long-range transport of pollutants from Sudbury.

Representatives of the shipping industry stated that shipping wastes made a very small contribution to the total input of waste into the lakes. Personal wastes from vessels were seen as a minimal contribution to the whole and existing regulations were thought to be sufficient. The United States and Canadian regulations for shipping wastes, while not identical, were said to be compatible because they achieved the same goal. Other witnesses were concerned about winter navigation and potential oil spills, and believed that there should be more stringent requirements regarding spills.

Regarding nuclear wastes and radioactivity, it was stated that the assimilative capacity of Lake Superior for radioactivity should be identified and common United States/Canada standards for radioactivity should be established. Several witnesses stated that the possibility of using thermal waste heat for municipal heating should be explored.

A number of representatives of environmental groups expressed concern that the existing legislation concerning the environment was not being enforced. It was stated that industries should be fined for lack of compliance, and that the "polluter should pay" for clean-ups.

Several comments were made at the hearings regarding the desire for a greater amount of public information and public education. Appreciation was expressed for the efforts of the Commission for greater public participation through the pre-hearing workshops. It was stated that public education should go hand-in-hand with any new environmental legislation.

The issue of erosion was discussed by several witnesses. It was believed that careful shoreline development and control of dredging would lessen erosion. Some witnesses stated that more careful regulation of lake levels would also be beneficial.

Other witnesses stated that the highest priority should be given to the potential effects on human health of constituents found in the water; therefore, the best treatment should be applied to wastewater in order to ensure a safe water supply. Comment was also received regarding the need for a greater emphasis on recycling and recovery of waste materials rather than on water, land, or air disposal. One industrial representative stated that the recommendation regarding discharge of metals, if implemented, would put his copper company out of business.

5. STATUS OF THE UPPER LAKES

For purposes of this study, the Reference Group classified water as nondegraded, degraded, or polluted. Nondegraded water is defined as high quality water which shows no significant change as a result of human activity. Degraded water shows the effects of human activity that may result in occasional violations of water use objectives, which are designed to protect the most sensitive water use. Polluted water shows frequent or severe violations of water quality for which remedial programs are required.

Pollution or degradation occurs when a water body is unable to assimilate the material discharged to it without adverse changes in water quality. The ability to assimilate a discharged waste material without an adverse effect depends on three factors: the quantity and the persistence of the material discharged and the physical characteristics of the receiving water body. Persistence refers to the ability of a substance to resist breaking down into an innocuous form.

Harbours and embayments comprise only a small fraction of the total volume of a lake, but impairment most often occurs there because these are the receiving waters for most point source discharges. Further, the geography and the bathymetry of each harbour or embayment result in a restriction in the exchange of the receiving water with water from the adjacent portion of the lake. This allows a pollutant discharged into a harbour or embayment to build up and impact that area. Water exchange patterns and therefore pollutant dispersal are unique to each geographic area; they are also complex and not well understood.

In some cases the quantity and/or the persistence of the material discharged also results in measurable pollution or degradation effects in the water, sediment, or fish in the adjacent nearshore zone outside the harbour or embayment. In extreme cases, measurable degradation from point sources can be detected in the open water of the lake itself. Thus, what is discharged must be considered not only for its impact on the immediate receiving water but also for its potential for contributing to impairment in the open lake.

The water quality of the Upper Lakes was evaluated by the Upper Lakes Reference Group with regard to twelve factors: nutrient enrichment (phosphorus), microbiology, metals, organic contaminants, solids, asbestos, spills, lake level regulation, dredging, vessel wastes, thermal inputs, and radioactivity. This chapter details the Reference Group's findings.

As found by the Reference Group, the Commission finds that several localized areas of the Upper Lakes have been adversely impacted by one or more of the twelve abovementioned factors, indicating that their local assimilative capacity has been exceeded. For most discharged materials, effects have generally not been detected beyond the immediate receiving waters. Moreover, in most cases, these factors do not appear to have caused any injury to the health or property of the other country. They do, however, adversely affect water quality and can also limit the ability of the Upper Lakes to handle future inputs.

Three factors were identified as also being potential whole-lake concerns: nutrient enrichment from phosphorus loadings, persistent synthetic organic contaminants, and metals. The adverse effects of these factors can include limitations on human consumption of water and fish, as well as possible loss of fisheries and recreational opportunities and the capacity for future growth. With respect to two of these three factors - toxics and metals - the assimilative capacity of the entire lake has been or may soon be exceeded. In these circumstances, the Commission believes that continued inputs of these substances on either side of the border will likely adversely affect health and property on the other side of the border.

Findings regarding pollution and degradation from the twelve factors identified above are first detailed for specific affected local geographic areas of the Upper Lakes; these areas are identified on Figures 4 and 5 for Lake Superior and Lake Huron, respectively. Transboundary impacts are noted where relevant. This chapter then considers whole-lake aspects of nutrient enrichment, organic contaminants (toxics), and metals. Lastly, because the atmosphere is a major recognized pathway for materials input, the effects of airborne pollution on water quality are discussed.

WATER QUALITY FINDINGS FOR SPECIFIC GEOGRAPHIC AREAS

The Reference Group identified numerous areas of reported pollution or degradation caused by discharges from municipalities and industries and/or by nonpoint inputs. These areas and the point source dischargers into them are listed in Tables 5 and 6 for Lake Superior and Lake Huron, respectively. Major causes of pollution are discussed in detail in this section. Table 7 provides a list of localized phosphorus concentrations, while Table 8 shows the Reference Group's present and projected phosphorus loadings to the Upper Lakes.

LAKE SUPERIOR BASIN

THUNDER BAY

The inner harbour and the adjacent section of the outer harbour of Thunder Bay are contaminated by local industrial and municipal wastewater discharges. The most seriously affected area is the lower Kaministikwia River and the area around its mouth. Remedial programs have been implemented to alleviate some of the identified concerns; however, future growth will increase the stresses on Thunder Bay.

The total phosphorus concentration in Thunder Bay (Table 7) increased considerably between 1970 and 1974, but it was not possible, on the basis of the limited phytoplankton production data available, to draw specific conclusions on the significance of the higher phosphorus level. The dissolved oxygen concentration has remained high, indicating no shift toward eutrophication. The factors controlling the trophic state in Thunder Bay are not known; the relatively low water temperature may be important in preventing adverse effects.

Because there has been no change observed in the trophic state of Thunder Bay, no nutrient removal from municipal wastewaters (which account for 20% of the phosphorus input) or from industrial wastewaters (which account for 25% of the input) is planned. With the predicted growth of the City of Thunder Bay, increased nutrient input is expected to occur. This could provide a critical

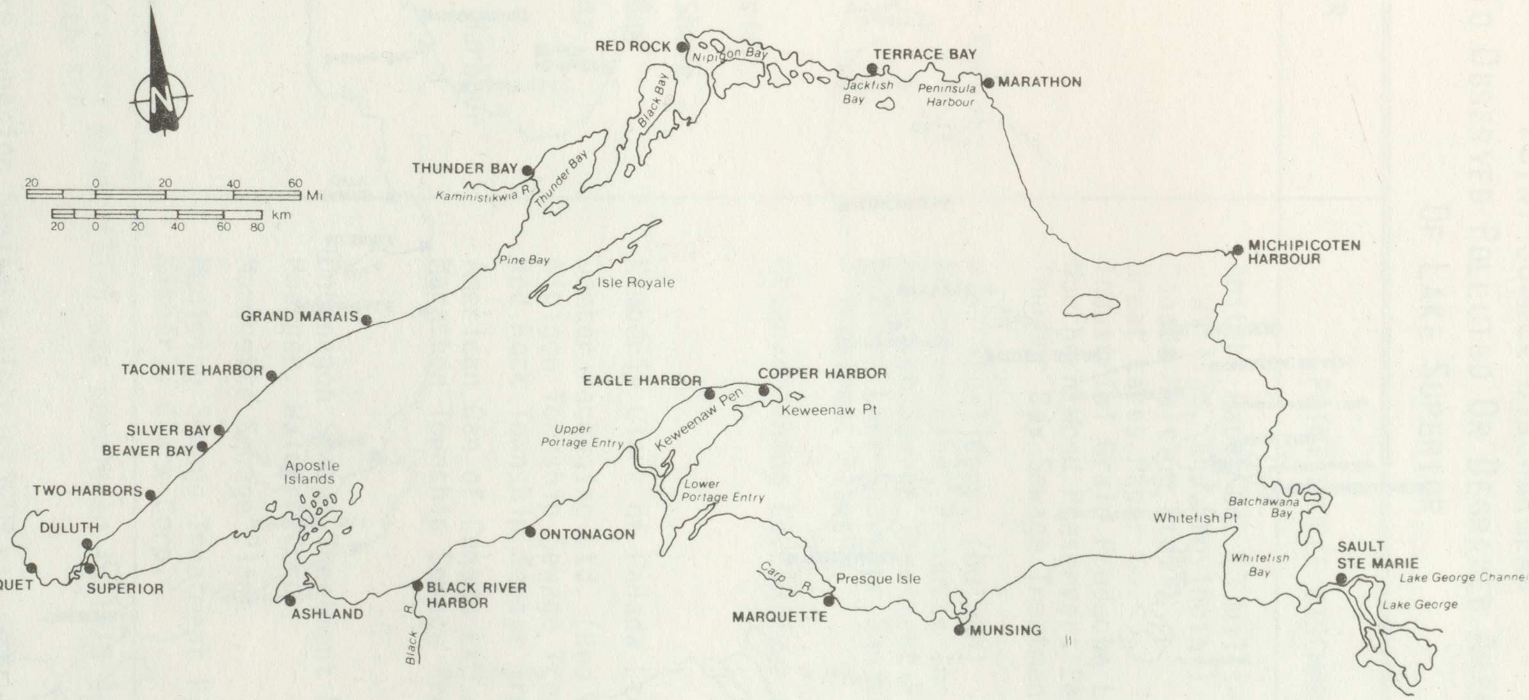

FIGURE 4- LOCATION MAP OF LAKE SUPERIOR

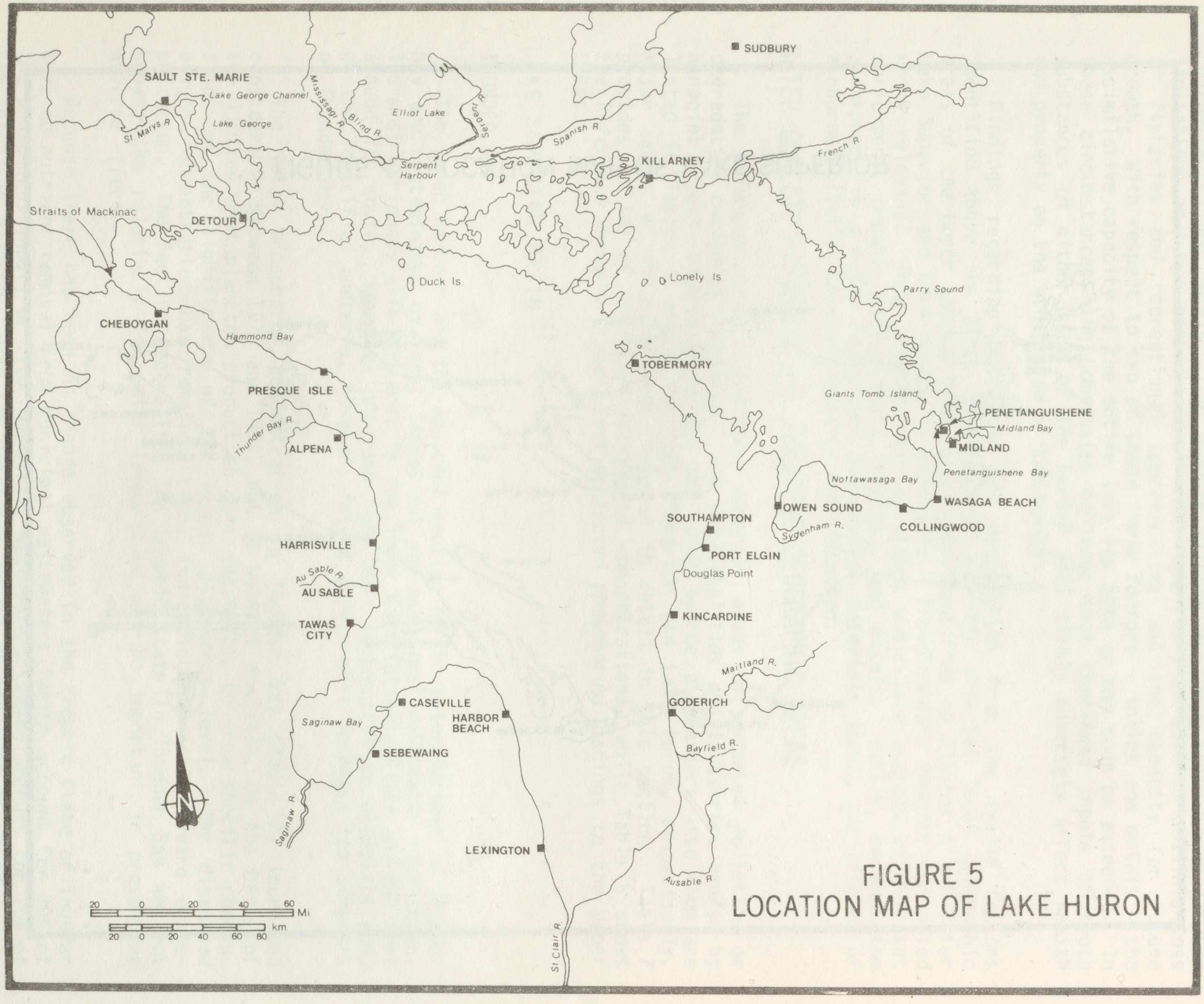

FIGURE 5
LOCATION MAP OF LAKE HURON

TABLE 5

Point-Source Dischargers To Observed Polluted Or Degraded Areas Of Lake Superior

RECEIVING WATER OR LOCATION	POINT SOURCE DISCHARGER
Thunder Bay	Abitibi Paper Co. (3 mills-Thunder Bay, Fort William, and Provincial) Canada Malting Ltd. Great Lakes Paper Co. Industrial Grain Products Ltd. Northern Wood Preservers Ltd. Thunder Bay Sewage Treatment Plant[a]
Duluth-Superior Harbor	U.S. Steel Corp. (Duluth) Superior Fiber Products Inc. (Superior) Superior Sewage Treatment Plant Western Lake Superior Sanitary District Sewage Treatment Plant[b]
Western Arm of Lake Superior	Reserve Mining Co. (Silver Bay)
Ontario North Shore -	
Jackfish Bay	Kimberly Clark of Canada Ltd. (Terrace Bay)
Nipigon Bay	Domtar Packaging Ltd. (Red Rock) Nipigon Township Sewage Treatment Plant Red Rock Township Sewage Treatment Plant
Peninsula Harbour	American Can of Canada Ltd. (Marathon) Marathon Township Sewage Treatment Plant
South Shore -	
Ontonagon	Ontonagon Sewage Treatment Plant Hoerner, Waldorf Corp.
Marquette	Marquette Sewage Plant
Munising	Munising Sewage Treatment Plant Kimberly Clark Corp.

a. This sewage treatment plant (STP) was completed in 1978 and replaced the North STP and the South STP.

b. The Western Lake Superior Sanitary District STP was completed in 1978 and will become fully operational during 1979. This new plant replaced the following direct dischargers to Duluth-Superior Harbor: Potlatch Corp. (Cloquet), Cloquet STP, Conwed Corp. (Cloquet), Continental Oil Co. (Wrenshall), Fairmount STP, Main Duluth STP, Scanlon STP, Carlton STP, Wrenshall STP, Jay Cooke State Park and STP, Gary New Duluth STP, and Smithville STP.

TABLE 6

POINT-SOURCE DISCHARGERS
TO OBSERVED POLLUTED OR DEGRADED AREAS
OF LAKE HURON

RECEIVING WATER OR LOCATION	POINT SOURCE DISCHARGER
St. Marys River	Sault Ste. Marie, Ontario Sewage Treatment Plant
	Algoma Steel (Sault Ste. Marie, Ontario)
	Abitibi Paper Co. (Sault Ste. Marie, Ontario)
	Domtar Chemical (Sault Ste. Marie, Ontario)
North Channel -	
Serpent Harbour	Elliot Lake Sewage Treatment Plant
	Rio Algom Mines (Elliot Lake)
	Denison Mines (Elliot Lake)
Spanish River Mouth	Eddy Forest Products (Espanola)
Blind River	Blind River Sewage Treatment Plant
Cottage Country Shoreline of Georgian Bay -	
Collingwood	Collingwood Sewage Treatment Plant
	Collingwood Shipyard
Penetang-Midland Area	Port McNicoll Sewage Treatment Plant
	Penetanguishene Sewage Treatment Plant
	Midland Sewage Treatment Plant
	Penetanguishene Mental Health Hospital
Parry Sound	Parry Sound Sewage Treatment Plant
Owen Sound	Owen Sound Sewage Treatment Plant
Tobermory	St. Edmunds-Tobermory Sewage Treatment Plant
Saginaw Bay, including dischargers upstream in the Saginaw River Basin	Alma Sewage Treatment Plant
	Bay City Sewage Treatment Plant
	Bridgeport Township Sewage Treatment Plant
	Buena Vista Township Sewage Treatment Plant
	Dow Chemical (Bay City)
	Dow Chemical (Midland)
	Flint Sewage Treatment Plant
	Flushing Sewage Treatment Plant
	General Motors Corp. (Bay City)
	General Motors Corp., Buick (Flint)
	General Motors Corp., Fisher Body (Flint)
	General Motors Corp., Chevrolet (Flint)
	General Motors Corp., Metal Castings Plant
	Genessee County District #2 Sewage Treatment Plant
	Genessee County District #3 Sewage Treatment Plant
	Michigan Sugar Co. (Caro)
	Michigan Sugar Co. (Carrolton)
	Michigan Sugar Co. (Sebewaing)
	Monitor Sugar Co. (Bay City)
	Midland Sewage Treatment Plant
	Mt. Pleasant Sewage Treatment Plant
	Owosso Sewage Treatment Plant
	Peet Packing Co. (Chesaning)
	Saginaw Township Sewage District
	Saginaw Sewage Treatment Plant
	Total Leonard (Alma)
	Velsicol Chemical Corp. (St. Louis)
	Zilwaukee Sewage Treatment Plant
Main Lake Shoreline -	
Tawas City	Tawas City Sewage Treatment Plant
Lexington	Lexington Sewage Treatment Plant
Cheboygan	Cheboygan Sewage Treatment Plant
	Charmin Paper Co.
Alpena	National Gypsum Co., Huron Cement Division
	Alpena Sewage Treatment Plant
	Abitibi Corp.
	Fletcher Paper Co.
	Besser Co.
Harbor Beach	Hercules, Inc.
Goderich	Goderich Sewage Treatment Plant

TABLE 7

TOTAL PHOSPHORUS CONCENTRATIONS IN THE UPPER LAKES

WATER BODY	AVERAGE ANNUAL CONCENTRATION (µg/L)
LAKE HURON	
Main Lake	4.5
North Channel	4.5
Georgian Bay	4.7
Inner Saginaw Bay	58 (2-290)
Penetang-Midland	20
Alpena	54
Harbor Beach	24
Goderich	30
Tobermory	2-18
Owen Sound	16
Collingwood	25
LAKE SUPERIOR	
Open Waters	4.0
St. Louis Bay	100-200
Marquette	100
Thunder Bay	55
Munising	16
Jackfish Bay	4-70
Nipigon Bay	3-20

Table 8

Present And Projected Phosphorus Loadings To The Upper Lakes

(in tonnes per year)

	LAKE SUPERIOR	MAIN LAKE HURON[a]	SAGINAW BAY	GEORGIAN BAY	NORTH CHANNEL
M & I Loadings					
Direct M	132	70	-	60	60
Direct I	99	67	-	0	14
Indirect M & I	369	947	-	37	68
Total M & I in 1974	600	1084	800	97	142
Scheduled Reductions[b]	200	700	600	0	0
M & I Loadings After Scheduled Reductions	400	384	200	97	142
Total Lake Loadings					
Before Scheduled Reductions	4140	3720	1310	928	1221
After Scheduled Reductions	3940	3020	710		
Percent Total Loading From M & I Sources					
Before Scheduled Reductions	14%	29%	61%	10%	12%
After Scheduled Reductions	10%	13%	28%		
Estimated Additional Reductions If All	80	10	-	25	75
Other M Dischargers Achieved 1.0 mg/L[b,c]	2%	<1%	-	3%	6%
Estimated Additional Reduction If All	30	60	100	35	10
M Dischargers Went From 1.0 to 0.5 mg/L[b,c]	<1%	2%	14%	4%	<1%
Projected Loading in 2020	4770	4230	-	1179	1700

a. Including Saginaw Bay
b. To be achieved without flow augmentation
c. Based in part on data presented in Appendix C to the 1977 Annual Report of the Great Lakes Water Quality Board. These estimated reductions are only approximate but of the correct order of magnitude.

stress on the Bay and could result in significant deterioration. Implementation of appropriate municipal and industrial phosphorus control is indicated to avoid potential future nutrient problems in the Bay. To this extent, under the terms of the 1978 Water Quality Agreement, relating to local conditions, the limit of a maximum phosphorus effluent concentration of 1 mg/L is applicable. Further, since Canada Malting Ltd. discharges via the municipal sewage treatment plant, municipal phosphorus removal capability would also reduce the industrial phosphorus input to Thunder Bay.

The Reference Group found that both municipal and industrial discharges were contributing to bacteriological degradation in and around Thunder Bay. The recently completed municipal primary sewage treatment plant provides treatment for essentially all municipal sewage discharges, including combined sewer discharges. However, since industrial discharges also contain sanitary wastes, bacterial degradation will continue until remedial measures are implemented on these sources.

Although lake trout and sediment in Thunder Bay exhibit elevated mercury levels, these appear to be the result of past discharges. Elevated concentrations of mercury occur in sediments in a zone extending from Thunder Bay to a point southwest of the international boundary in the deeper waters of the Duluth depositional basin; these deposits are the result of mining in the Thunder Bay area around the turn of the century. A more recent source of mercury was the chlor-alkali plant of Dow Chemical Company on the Kaministikwia River; this plant was closed in 1973. The mercury-bearing sediments will, in time, be effectively separated from the water column as new sediment is deposited on the lake bottom. Thus, levels in fish should decrease to within accepted criteria without additional remedial programs.

Excessive levels of compounds which can cause objectionable taste and odour are traceable to the Great Lakes Paper Company mill in Thunder Bay. Ongoing or planned remedial measures are expected to reduce discharges containing such compounds to levels in compliance with the Agreement and Ontario objectives, but because of the schedule in the control orders, compliance is several years away. This time frame is excessively long in relation to the purpose of the Agreement.

Thunder Bay is the location of about 75% of the maintenance dredging in the Canadian portion of the Lake Superior Basin. Most of the sediments contain organic materials and mercury. There has been only a minimal amount of dredging, however, in recent years. Uncontaminated material is presently disposed of well offshore and contaminated material deposited in a semi-enclosed basin. A diked disposal area for future dredging is under development.

DULUTH-SUPERIOR HARBOR

Water quality in Duluth-Superior Harbor is adversely affected by municipal, industrial, agricultural, and natural sources; point-source dischargers are listed in Table 5. The harbour consists of St. Louis Bay and Superior Bay; the former is upstream of the latter. Physical and chemical properties are highly variable but, normally, water quality generally improves as one proceeds toward the lake. However, the controlling factor is the wind; an offshore wind can introduce high-quality lake water well up into the harbour. Outflow of the water after cessation of the wind in effect flushes the harbour.

Duluth-Superior Harbor was extensively studied by the Reference Group during 1973-75. Eighty percent of the annual phosphorus loading of 270 tonnes was found to come from point-source discharges. Based on observed nutrient loadings and biological indicators, Duluth-Superior Harbor was eutrophic; the phosphorus concentration in St. Louis Bay was 100-200 μg/L, compared to 4 μg/L in the open waters of Lake Superior. Nutrients and BOD loadings from organic material were contributing to low dissolved oxygen values, often in violation of Minnesota standards. The levels of chlorophyll α (a measure of the amount of algae in the water) were only moderately high, but this may be attributed to high turbidity restricting the amount of light, on which algae are dependent for growth. Fecal coliform, phenols, and copper levels in Duluth-Superior Harbor were often in excess of Minnesota standards.

Remedial measures have since been completed or undertaken to restore the water quality of Duluth-Superior Harbor to within jurisdictional and Agreement values.

Coliform levels and nutrient, BOD, and suspended solids concentrations are expected to decrease, and dissolved oxygen levels are expected to recover when the recently completed $100 million Western Lake Superior Sanitary District wastewater treatment plant is fully operational. Start-up commenced in October 1978. This plant replaces numerous smaller plants and treats both municipal and industrial wastewater.

Phosphorus removal capability will reduce the annual loading by about 160 tonnes. When this target is met, municipal and industrial point sources will be contributing only about half of the total phosphorus loading to the harbour. The need for additional nutrient removal measures would depend on to what extent the harbour has been restored.

Discharge requirements have been placed upon some other direct municipal and industrial discharges to the harbour. Also, a rehabilitation program was initiated in 1976 to patch broken sanitary sewer lines in Duluth and to stop sanitary sewer bypasses. Flow monitoring is being conducted to further evaluate the amount of infiltration of sanitary sewers. The adequacy of the programs should be assessed after the harbour waters have had an opportunity to respond.

Although these remedial measures will improve the quality of St. Louis Bay and Superior Bay, the accumulated benthic sludges in the lower St. Louis River will remain. The sludges contain BOD from past discharges and, as a result, low dissolved oxygen levels will persist in the river for many years to come.

Dredging in Duluth-Superior Harbor accounts for approximately 90% of all dredging in the U.S. portion of the Lake Superior Basin. However, the sediment is contaminated and, although its effect on the water column is not entirely known, this has led to the prohibition of open water disposal of the spoil. A confined dredge spoil disposal site was under construction during 1978 and disposal will begin there in 1979. The U.S. Army Corps of Engineers is studying the pollution potential of material dredged from Duluth-Superior Harbor and will also monitor water quality in the vicinity of the disposal site after it becomes operational. The results of these studies, when complete, should be considered to determine if additional measures are necessary.

WESTERN ARM OF LAKE SUPERIOR

The two major adverse influences on the western arm of Lake Superior are the Reserve Mining Company discharge at Silver Bay, Minnesota and the red clay erosion area along the Wisconsin shoreline.

The discharge of taconite tailings waste from Reserve Mining Company results in deposits of tailings on the lake bottom and dispersal of asbestiform fibres in the waters of the western arm of Lake Superior. The discharge has also created a tailings delta. The discharge, which is denser than the lake water, flows down the face of this delta without much deterioration until it reaches a trough about 300 metres deep and about 10 kilometres offshore, where most of the tailings are deposited. The thermocline (temperature gradient), however, can split the density current, resulting in some dispersal of tailings and of asbestiform fibres in the water column. Also, some deposited tailings and asbestiform fibres are resuspended from the trough and distributed over much of the western arm of Lake Superior by the prevailing counterclockwise current, upwellings, and storms and can be found almost to the Keweenaw Peninsula. Tailings presently cover the lake bottom to a depth of at least 0.25 cm over an area of 130 km^2 (Figure 6).

The tailings deposits have resulted in an adverse shift in the benthic community population and structure. The tailings discharge causes a local violation of the 1978 Agreement objective for settleable and suspended solids, reduces the aesthetic enjoyment of the water, violates the Minnesota effluent limitations for turbidity and suspended solids, and may contribute to lake enrichment.

More significant than the tailings as a whole is the amphibole asbestiform fibre fraction of the tailings discharge. Because of their small size, once suspended, the fibres discharged at Silver Bay tend to remain suspended in the water column. Fibres have been detected downstream in high numbers in the water supplies of Beaver Bay, Two Harbors, Duluth, and Cloquet (Figures 4 and 7).

The U.S. federal Court of Appeals has ruled that, because of the presence of asbestiform fibres, the tailings discharge violates the Federal Water Pollution Control Act in that it endangers public health and welfare.

As a result of extended litigation by U.S. EPA, the State of Minnesota, and environmental groups, the courts have ruled that the discharge to Lake Superior must cease by April 15, 1980. Reserve is presently constructing an on-land disposal site. This will eliminate the source; however, the fibres do not degrade and will remain in the lake indefinitely. Further, because of resuspension from the tailings deposits on the bottom and erosion from the existing tailings delta even after the discharge ceases, and the absence of any feasible means of amelioration, the fibres will remain in the water of Lake Superior for many years to come. Present data suggest that the problem arising from the Reserve Mining operation will probably not extend beyond the western arm of Lake Superior.

Epidemiological studies have shown that *inhalation* of asbestos fibres is associated with asbestosis, respiratory system cancer, gastrointestinal cancer, and pleural and peritoneal mesothelioma. Asbestos fibres in drinking water may also constitute a health hazard, but studies have not yet determined whether asbestos ingestion is either safe or hazardous. Several long-term studies are in progress to define the health effects of ingested asbestos.

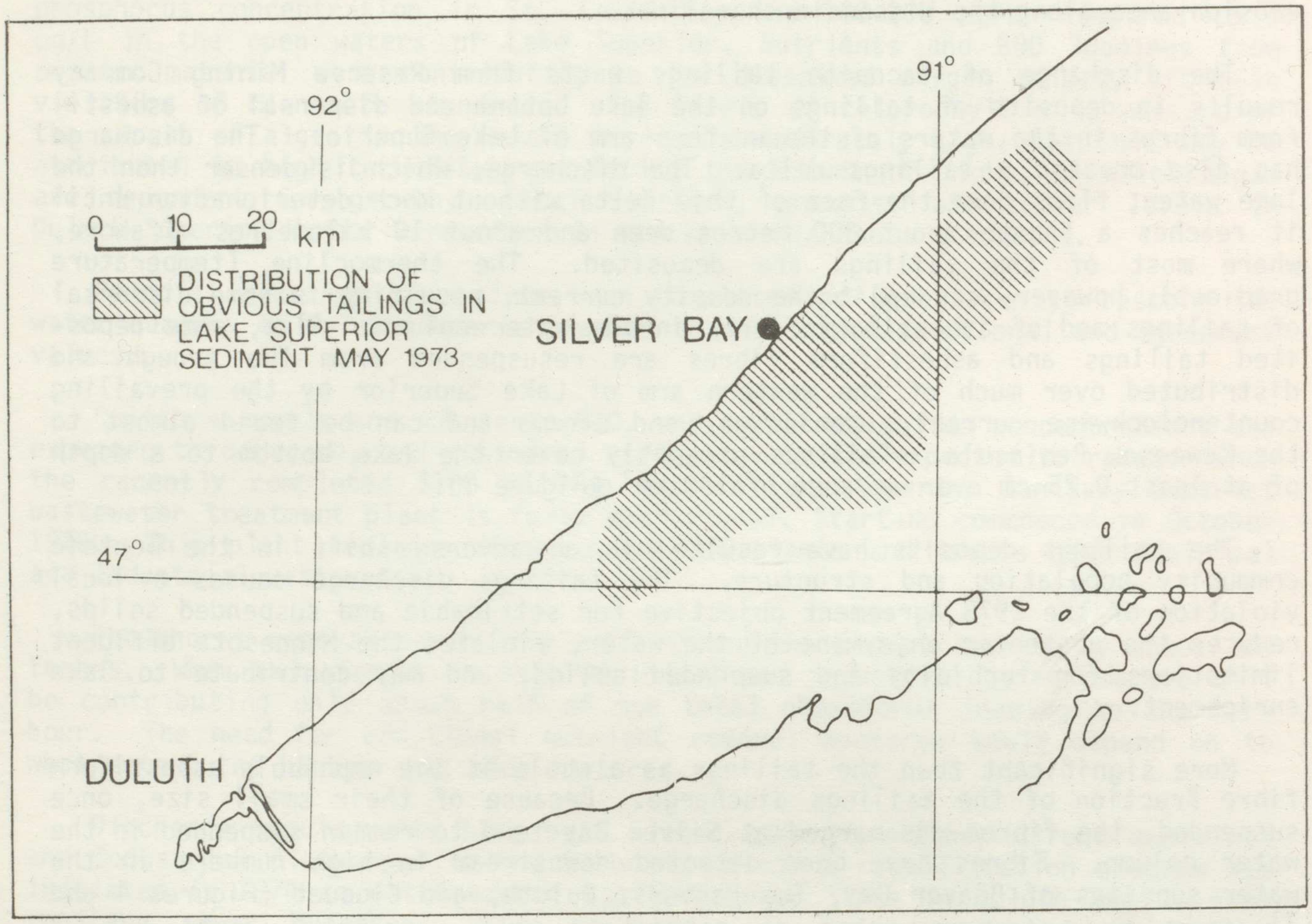

FIGURE 6 - DISTRIBUTION OF TACONITE TAILINGS IN LAKE SUPERIOR SEDIMENT BASED UPON VISUAL EXAMINATION OF SURFACE SEDIMENT SAMPLES

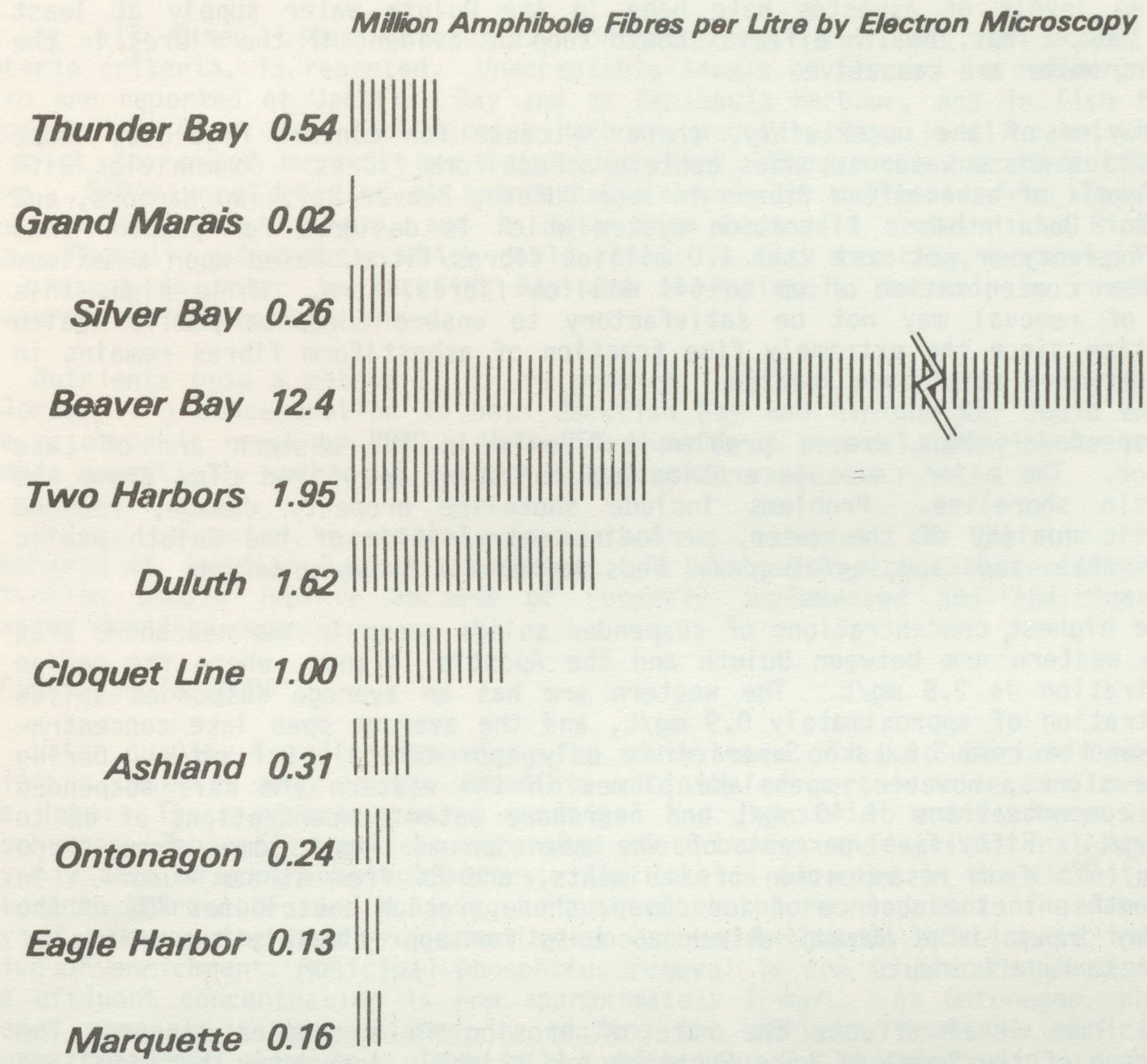

FIGURE 7- WESTERN LAKE SUPERIOR AVERAGE CONCENTRATIONS OF AMPHIBOLE ASBESTOS FIBRES IN POTABLE WATER INTAKES

The latency period between initial exposure to asbestos and resultant diseases is generally from 20 to 40 years. Reserve has been discharging since 1955 and elevated levels of asbestos have been in the Duluth water supply at least since 1964. Thus, health effects should soon be evident if the fibres in the drinking water are causative.

In view of the uncertainty, there is cause for concern regarding those communities whose water supplies contain asbestiform fibres. Communities with high levels of asbestiform fibres include Duluth, Beaver Bay, Two Harbors, and Cloquet. Duluth has a filtration system which is designed for greater than 99% efficiency or not more than 1.0 million fibres/litre, based upon a maximum raw water concentration of up to 644 million fibres/litre. While high, this level of removal may not be satisfactory to ensure adequate public health protection since the extremely fine fraction of asbestiform fibres remains in the water.

Suspended solids are a problem but only in the western arm of Lake Superior. The major cause is erosion and resuspension of red clay along the Wisconsin shoreline. Problems include shoreline property damage, reduced aesthetic quality of the water, periodic contamination of the Duluth public water intake, and clogging of gravel beds needed for trout spawning.

The highest concentrations of suspended solids occur in the nearshore area of the western arm between Duluth and the Apostle Islands, where the median concentration is 2.8 mg/L. The western arm has an average suspended solids concentration of approximately 0.9 mg/L, and the average open lake concentration for the rest of Lake Superior is only approximately 0.2 mg/L. During intense storms, however, open-lake plumes in the western arm have suspended solids concentrations of 40 mg/L and nearshore water concentrations of up to 1000 mg/L. Fifty-five percent of the mean annual input comes from shore erosion, 37% from resuspension of sediments, and 8% from stream runoff. In warm months, in the absence of ice cover, shore erosion contributes 70% of the red clay input. The Nemadji River accounts for approximately two-thirds of the stream runoff input.

The lake level affects the rate of erosion in a complex manner. The regulation of the level of Lake Superior has slightly increased the mean lake level; a higher mean lake level tends to increase erosion. On the other hand, regulation has slightly decreased the peak level and the range of water level fluctuation. It is also established that the greatest erosion takes place during storms, which increase wave action and cause surges in lake level. Thus, the net influence of regulation is difficult to assess. The Reference Group concluded the long-term effect of lake-level regulation on red clay erosion is slight; red clay erosion is a natural phenomenon, essentially unaffected by man's activities.

The Reference Group also concluded that stabilization of the shoreline would be difficult regardless of the lake level because of the nature of the soil. However, studies have been initiated to determine how red clay erosion upstream in the drainage basin can be controlled.

ONTARIO NORTH SHORE

Along the Ontario shoreline of Lake Superior east from Thunder Bay to Sault Ste. Marie, the general water quality is good. Significant degradation occurs only in the immediate vicinity of municipal and/or industrial outfalls at Jackfish Bay, Nipigon Bay, and Peninsula Harbour (Table 5). All three locations are pulp and paper production centres: Kimberly Clark of Canada Ltd., Domtar Packaging Ltd., and American Can of Canada Ltd., respectively.

At all three sites, bacterial contamination, sometimes in excess of Ontario criteria, is reported. Unacceptable levels of mercury in sediment and fish are reported at Jackfish Bay and at Peninsula Harbour, and in fish from Nipigon Bay, Black Bay, Michipicoten Harbour, and Pine Bay; in all cases where a point source of mercury has been identified, the source has been closed down. PCB's were detected at unacceptable levels in sediments from Jackfish Bay and Peninsula Harbour, and in fish from Peninsula Harbour and Nipigon Bay. Phenolic substances, which could result in fish tainting, were reported as present in water in Jackfish Bay and in Peninsula Harbour; no remedial measures are presently planned.

Nutrients pose a potential future problem. Without phosphorus removal the chlorophyll α concentration in both Jackfish Bay and Nipigon Bay could enter the mesotrophic range by 2020. With 85% phosphorus removal, the levels would remain essentially unchanged, in the oligotrophic range.

Unless corrected, bacterial degradation as a result of the industrial discharge at Jackfish Bay will continue. In Nipigon Bay, the bacteriological situation should improve because of recently implemented and additionally planned remedial measures.

MICHIGAN SOUTH SHORE

Water quality is also good along the south shore of Lake Superior. Degradation is observed only in the immediate vicinity of certain river inflows to the lake. These rivers receive municipal and industrial point-source waste discharges (Table 5); upstream watershed disturbances and agricultural activity may also be contributing factors. The lake is impacted in the vicinity of Ontonagon, Marquette, and Munising because of phosphorus inputs to the lake by way of rivers; the benthic community at each river mouth location is indicative of enrichment. Municipal phosphorus removal is now in place at Munising; the effluent concentration is now approximately 1 mg/L. At Ontonagon, phosphorus removal is accomplished by routing the effluent from the municipal sewage treatment plant to a paper mill, which uses the phosphorus in its waste treatment operations. Phosphorus removal facilities are under construction at Marquette and will be on line in the fall of 1979.

Inadequate operation of disinfection facilities at municipal sewage treatment plants has resulted in elevated coliform counts at Black River Harbor, Ontonagon, Marquette, and Munising.

Severely degraded sediments occur at Ontonagon and Munising, as a result of inadequately treated sewage, and at Upper Portage Entry because of past mining activities. Under U.S. EPA dredge spoil guidelines, the sediments are considered polluted, at Ontonagon for chemical oxygen demand and total Kjeldahl nitrogen; at Munising for chemical oxygen demand, total Kjeldahl nitrogen, zinc, lead, and total volatile solids; and at Upper Portage Entry for copper and zinc. At all three locations, the benthic community is degraded. Maintenance dredging of polluted sediment is undertaken at Ontonagon; the polluted spoil is disposed of on land.

The concentration of copper in water is elevated at Upper and Lower Portage Entries, as a result of past mining activities, and also at Ontonagon and Marquette.

Human consumption of fat lake trout caught at Munising, Marquette, and Whitefish Point is limited because mercury levels exceed the 0.5 mg/kg U.S. Food and Drug Administration guideline. Mean levels of PCB's exceed the 5 mg/kg U.S. guideline in fat lake trout caught at Black River Harbor, Munising, and Marquette. Some individual fat lake trout caught at Black River Harbor, Lower Portage Entry, Copper Harbor, Marquette, and Munising exceed the 5 mg/kg DDT guideline. Only at Black River Harbor, however, does the mean value exceed the guideline.

LAKE HURON BASIN

ST. MARYS RIVER

The St. Marys River continues to be degraded by municipal and industrial discharges from Sault Ste. Marie, Ontario. Loadings of cyanide, phenols, ammonia, and other materials to the St. Marys River from Algoma Steel were sufficiently high in 1947-48 for the Commission to recommend in its 1951 report to Governments that measures be taken to abate the discharges in order to correct identified pollution problems. However, loadings were considerably higher in 1974, indicating that remedial measures have neither corrected the problems nor kept pace with expansion.

The discharge of industrial waste from Algoma Steel Corporation has resulted in sediment concentrations exceeding U.S. EPA and/or Ontario dredge spoil disposal guidelines for phenolic substances, oil, cyanide, iron, and zinc. For example, iron concentrations as high as 44% by weight are recorded in the surface sediments for the first 3 km downstream from the discharge and exceed the guideline for 11 km. Severe disruption of the benthic macro-invertebrate community is observed for about 3 km downstream of the main outfall and up to 300 metres from shore. Elevated levels of iron and zinc are found in sediments on the U.S. side of the river downstream of Sault Ste. Marie, Ontario, as a result of transboundary movement. However, recorded levels do not exceed the guidelines across the international boundary and, fortunately, contaminated areas are not generally subject to maintenance dredging.

Cyanide levels in water average 0.28 mg/L downstream of the main Algoma outfall and exceed the Ontario permissible criterion of 0.2 mg/L for public water supply for about 0.3 km downstream. Both these values are higher than concentrations reported to be lethal to various species of fish. Levels in excess of the proposed water quality objective of 0.005 mg/L extend into the Lake George Channel. Cyanide loadings from Algoma Steel were 2280 kg/d in 1974, constituting more than 80% of the total input to Lake Huron from all sources. A major reduction in cyanide should be achieved beginning in 1979 with the final commissioning of a new byproduct recovery plant.

The concentration of phenolic substances in water exceeds the 1978 Agreement objective and the Ontario criterion for more than 11 km below the main Algoma outfall. The levels were reinforced by inputs from Domtar via the municipal sewer outfall. Transboundary movement was evident in Lake George where phenol levels exceeding the Agreement objective were found in U.S.

waters. There have been no confirmed reports, however, of fish tainting or of taste and odour problems in water supplies. In January 1976, Domtar began incineration of its wastes. At Algoma, the new by-product recovery plant mentioned above should significantly reduce phenolic discharges. Both cyanide and phenol levels should be monitored following implementation of remedial measures at Algoma Steel.

Bacterial levels in excess of the Agreement objectives and Ontario recreational use criteria occur due to sewer overflows and inadequate effluent disinfection at the municipal sewage treatment plant. No remedial measures are under way.

NORTH CHANNEL

The North Channel possesses high overall quality. However, degradation was found in the vicinity of Serpent Harbour, at the Spanish River mouth, and in that portion of the channel receiving inflow from the St. Marys River.

Serpent Harbour and the Spanish River mouth both exhibit developing phosphorus nutrient enrichment from tributary municipal and industrial discharges, but chlorophyll α levels are not sufficiently elevated to be of concern. If mines are reopened, nitrogen loadings from mine tailing areas could increase at the Serpent River mouth.

The St. Marys River is a major source of phosphorus loading to the North Channel. Although the loading rate indicates that the area should be in the mesotrophic range, chlorophyll α levels do not show any increase; they are about the same as in the oligotrophic open water of Lake Huron.

Bacterial levels in the northwestern portion of the North Channel are elevated because of loadings from the St. Marys River. Levels near the Blind River and at the mouth of the Spanish River are elevated due to the discharge of inadequately treated sewage.

Nickel concentrations are elevated in the sediments from several areas of the North Channel, including Serpent Harbour. The levels are due to natural mineralization and mining activities in the drainage basin. DDT has also been detected in the sediment of the Spanish River mouth and in Serpent Harbour; the source may have been past usage of DDT to control black flies. Phenols in the water of the Spanish River mouth are due to the Eddy Forest Products pulp and paper mill upstream at Espanola.

Radium activity (concentration) in Serpent Harbour continues to exceed the Ontario permissible criterion for surface drinking water supplies of 3 picocuries per litre as well as the 1978 Agreement objective, expressed as a dosage, of 1 millirem per year. Radium levels are lower, however, than values reported in previous years due to remedial measures initiated upstream at active mine sites in the Elliot Lake area subsequent to 1965, decreased mining activity in recent years, and natural decreases in stream flow. Pursuant to control orders issued in 1977, waste and drainage from both active and idle mining properties owned by Denison Mines Ltd. and by Rio Algom Ltd. meet the provincial guideline which was established in order to achieve compliance with the provincial drinking water criterion. However, because this guideline has not been applied to drainage from tailings areas at other idle or abandoned mines, the radium level in Serpent Harbour remains elevated above the drinking water criterion. The only local public water supply in the area is treated to reduce the radium concentration to within the criterion. No further remedial programs are under way, although the need for additional control programs in the Elliot Lake area is being assessed.

COTTAGE COUNTRY SHORELINE OF GEORGIAN BAY

Significant nutrient enrichment occurs in the nearshore waters of Georgian Bay in the vicinity of Collingwood, Penetang, and Midland and minor enrichment at Parry Sound, Owen Sound, and Tobermory. At Collingwood, phosphorus concentrations (Table 7) are sufficiently high to cause nuisance weed and algal growths. Municipal wastewater is a principal source of the nutrients; at Collingwood and at Midland, the phosphorus removal facilities are not operating properly. Other contributing factors are, at Collingwood and Penetang, the low flushing rate and assimilative capacity of the receiving water. Also at Collingwood, runoff and nutrients from suspended sediments may contribute. Enrichment at Parry Sound may become a problem in the future because of the limited nutrient assimilation capacity of the receiving water.

In Penetang Bay, municipal sources contributed about 87% of the phosphorus loading in 1973 and for Midland Bay, about 34%; for the Penetang-Midland area as a whole (defined as the area east of Giants Tomb Island), municipal point sources contributed about 24% of the total input.

For Penetang Bay, the sewage treatment plants are presently achieving a phosphorus effluent limitation of less than 1 mg/L, but the long (2.4 years) water retention time of the bay precludes achieving a higher level of water quality in the Bay. Improved alternative methods of phosphorus treatment or disposal are required to deal with this localized problem.

When the entire Penetang-Midland area is considered, 76% of the phosphorus input is from nonpoint sources, including unsewered domestic waste. A sizable portion of the population in the drainage basin, which includes the Severn River, is nonsewered.

The population of the cottage country is projected to increase. Much of this future population may be unsewered. For new cottage construction, Ontario requires a no-discharge tile drainage system which should allow for no discharge, directly or indirectly, to surface waters; where this is not feasible, a sewage holding and pump-out system is required. Pumped-out waste is conveyed to a municipal system for disposal. Ontario is presently implementing similar requirements for existing cottages.

At Collingwood, according to projections of chlorophyll α levels, by 2020, even with 85% phosphorus removal, growth will push the harbour into the eutrophic range. Similarly, at both Penetang and Midland, the projected chlorophyll α levels with 85% phosphorus removal would be in the mesotrophic range by 2020. Therefore, more stringent phosphorus loading limits may be required on present point sources and alternative waste collection, treatment, and disposal technology may be appropriate. Further, the phosphorus contribution from septic tanks and whether such systems are operating properly should be determined.

In the summer, total coliform levels sometimes exceed the Agreement objective at Penetang; the causes are inadequately disinfected waste, urban drainage, and possibly the heavy recreational use of the area. Fecal coliforms and fecal streptococci also exceed objectives at the Sydenham River mouth in Owen Sound in the summer. Appropriate disinfection and control measures should be undertaken.

Sediments at Collingwood Harbour have high concentrations of zinc, cadmium, and lead; these are attributable to local shipbuilding operations. Zinc concentrations in sediment were also high at Penetang, Midland, and Parry Sound Harbour. DDT and its metabolites have been detected in sediments from Tobermory, Owen Sound, Collingwood Harbour, Penetang, and Midland. Dieldrin has also been detected in Owen Sound Harbour, Penetang, and Midland. The presence of DDT and dieldrin is probably attributable to past agricultural use.

Owen Sound and Collingwood Harbour sediments also had high levels of PCB's; the sources are not known. PCB's were also detected in individual fish in excess of the Canadian health guideline of 2 mg/kg at Owen Sound, Tobermory, and Nottawasaga Bay. Walleye from Nottawasaga Bay also contain an average mercury concentration exceeding the Canadian health guideline of 0.5 mg/kg and walleye from the Penetang-Midland area approach the guideline. The mercury source is believed to be natural.

SAGINAW BAY

Saginaw Bay is one of the most polluted areas in the Great Lakes System; it violates numerous jurisdictional values and Agreement objectives. In addition, the 60-day flushing time of Saginaw Bay results in the transport of the contaminants in substantial quantities to the open water of southern Lake Huron. The Bay receives the wastewater generated by 1.2 million people living in its basin, numerous industries, and agricultural land runoff. Most pollutants enter the Bay via the Saginaw River. Virtually every use of Saginaw Bay has been affected or curtailed: water supplies (taste and odour and filter clogging), recreation (swimming and boating), and fishery (sport and commercial). Despite some remedial measures, problems could become more acute.

Saginaw Bay is considered to be naturally somewhat eutrophic, and this condition has been severely aggravated by the additional impact of human activities in its drainage basin. The stimulation of algal growth and the presence of undesireable species by nutrients is now and probably will continue to be the most serious water quality problem in Saginaw Bay. During 1973-75 the Saginaw River contributed approximately 1310 t/a of phosphorus through the Bay to Lake Huron (Table 8). This was 24% of the total phosphorus input (5520 t/a) to the entire lake and more than the amount entering the lake via the St. Marys River and the Straits of Mackinac combined. Municipalities in the river basin were responsible for approximately 61%, and nonpoint sources for approximately 39%, of the phosphorus input to the Saginaw River.

The Reference Group reported that phosphorus reduction to achieve an average phosphorus effluent concentration of 1 mg/L at all municipal sewage treatment plants in the Saginaw Bay Basin would reduce the annual phosphorus loading from municipal sources from 800 to 200 tonnes, or by about 75%. This 600 t/a reduction would represent about a 50% decrease in the total phosphorus input to Saginaw Bay.

Point-source phosphorus removal capability is now in place at almost all municipal sewage treatment plants in the Saginaw Bay Basin; by 1977, these facilities had effected a reduction in the annual phosphorus loading of about 475 tonnes. An additional annual reduction of about 100 tonnes will be achieved in 1979 when Flint completes its program. In addition, because of operational difficulties, some plants are not presently achieving the effluent goal of 1.0 mg/L. Proper operation, coupled with the recently enacted (October 1977) 0.5% limitation on phosphorus in laundry detergents, should result in all municipal plants meeting or exceeding their targeted load reduction and, hence, the goal reported by the Reference Group. With achievement of the 600 t/a reduction, point sources will be contributing only about 28% of the total phosphorus load to Saginaw Bay.

The phosphorus removal measures described above are expected to significantly help the aggravated situation in Saginaw Bay and to facilitate use of the Bay's water. However, these measures and even more stringent point source control measures may not be adequate to meet the Agreement objective of preventing nuisance algae and weed growth and completely restoring beneficial water use. For example, the 50% reduction in phosphorus loading to the Bay will reduce the average chlorophyll α concentration in the inner bay by about a third from 15.7 μg/L, but this concentration is still in the eutrophic range. Further, the undesireable blue-green algae would still be present, although there would be a significant reduction in their number and in the consequent water use problems.

If all sewage treatment plants in the Saginaw Bay Basin achieved an average phosphorus effluent concentration of 0.5 mg/L, the loading to the Bay, compared with the loading expected with achievement of a 1.0 mg/L limit, would be reduced by only about 100 more tonnes per year, a further reduction of only about 14%. Land application, if feasible, could ultimately reduce point source phosphorus loadings down to 20 t/a.

Nonpoint sources represent the major future input of phosphorus to Saginaw Bay. Although the nonpoint contribution to the total loading is large, any change in this loading from land runoff with change in land use should, qualitatively, be small. Nonpoint loadings can be mitigated by application of cost-effective land runoff control measures in the Saginaw Bay Basin. Such measures would help improve and maintain the Bay's overall quality at a higher level. A relatively substantial effort would be required in the basin, however, to alter the trophic state of Saginaw Bay further. In its report on the study conducted by the Pollution from Land Use Activities Reference Group, the Commission will deal in detail with possible reductions of phosphorus from nonpoint sources.

The Commission therefore believes that the new baseline loading value and the improved Bay conditions established by the 600 t/a phosphorus reduction can be maintained and even enhanced. However, the eutrophic trend in the Bay will not be completely reversed, and any future population growth and development would endanger the maintenance of the improved conditions unless they are held to zero or near-zero discharge. Further analysis, after completion of measures presently underway, would be required to refine the degree of danger.

Elevated coliform levels near the mouth of the Saginaw River have resulted in beach closures. Low dissolved oxygen levels, especially near the mouth of the river, have adversely affected benthic organisms and the fishery. Suspended solids have also affected the fishery and reduced the bay's aesthetic value through discolouration.

The PCB concentration is high enough (approximately 80-90 ng/L) to be detectable in the water at the mouth of Saginaw River, the only place in the Upper Lakes System where PCB's have been detected in the water. Phthalates also exceed the Agreement objective, and dieldrin is detectable in the water. The concentration of zinc in the water of Saginaw Bay is approaching a level documented to be toxic to certain aquatic organisms.

The sediments in the Saginaw River and in Saginaw Bay are contaminated with PCB's. Two reaches of the river have values in excess of 10 mg/kg, and a maximum value of 22.9 mg/kg has been reported. PCB levels in the sediment along the navigation channel, out from the mouth of the Saginaw River, are reasonably constant, averaging 1.5-2.0 mg/kg. A large area of the bay exhibits a low level of contamination.

Sediments in Saginaw Bay are also moderately polluted with zinc, lead, total Kjeldahl nitrogen, and chemical oxygen demand, with the most polluted areas near the Saginaw River mouth. Dibutyl phthalates were also detected. The sediments also act as a source of nutrients and toxic materials when the overlying waters become depleted; it is estimated that 50% of the phosphorus that settles in the bay during the year is later resuspended.

Of the volume of polluted sediments subject to dredging in the U.S. portion of the Lake Huron Basin, nine-tenths is from the Saginaw River; the spoil is disposed of in diked areas. Special dredging methods are required in the two areas of the river which are heavily polluted with PCB's. In addition, studies have been initiated to determine the cost and feasibility of various remedial actions to alleviate the elevated levels of PCB's in the sediment of the Saginaw River and of PBB's in the tributary Pine River.

The fishery in Saginaw Bay has suffered because of both environmental contamination and overfishing. Enrichment has resulted in a shift in the food organisms, indeed the entire aquatic population. Increased metal and organic contamination has limited the human consumption of the fish. In catfish samples, for example, most of the PCB and some of the DDT values reported exceed the U.S. health protection guidelines of 5 mg/kg as well as the Agreement objectives. A number of other exotic chlorinated organics were also reported as present in the fish.

As described above, municipal phosphorus removal presently coming on line to reduce the annual loading by 600 tonnes will improve the Bay's quality for the near term. Other remedial measures have been taken since 1965 by Dow Chemical Company at Midland and by Michigan Chemical Company (later Velsicol) at St. Louis to reduce chloride loadings and hence bring the dissolved solids concentration into compliance with the Agreement objective. Corrective steps have also been taken or initiated to substantially reduce point source discharges of metals and organics from several upstream dischargers.

Although the present trend is generally toward improvement, increased population and industrial activity in the Saginaw Bay Basin could reaggravate the condition of the Bay unless installation of new treatment facilities keeps pace with growth. For phosphorus, the controls required will tend much closer to 100% removal from point source discharges. For all municipal and industrial discharges, consideration of other control measures, such as increased treatment efficiency, alternative disposal methods (such as land application), innovative technology, recycling wastewater and waste recovery is required. Unless and until the present municipal and industrial waste loadings into the basin can be dramatically reduced, the decision will have to be made to sacrifice either certain future uses of the Bay or growth and development.

MAIN LAKE SHORELINE

The nearshore waters of the southern part of the main body of Lake Huron are adversely affected by man's activities, as are several other localities along the main lake shoreline which receive municipal wastewater discharges. The water quality of the remaining nearshore waters in the lake is similar to the high quality of the open lake waters.

Concentrations of chlorophyll α and moderately high algal populations indicate mesotrophic conditions along the U.S. shoreline of Lake Huron, downstream of eutrophic Saginaw Bay. The benthos at Tawas City and Lexington, as a result, are dominated by pollution-tolerant species.

The Ontario shoreline south of Goderich also shows seasonal chlorophyll α levels and algae populations characteristic of the mesotrophic range. Drainage from tributaries, primarily the Maitland River, is responsible. The Southampton and Port Elgin areas also exhibit minor nutrient enrichment.

Municipal discharges of phosphorus have enriched the receiving water on the U.S. shoreline at Cheboygan, Alpena, and Harbor Beach (Table 7). The problem at Alpena is compounded by the long retention time of harbour water, but nutrient removal, now in place, should improve that situation.

As a result of municipal wastewater discharges, bacterial levels in excess of the Agreement objectives are frequently observed at Goderich, Cheboygan, Alpena, Tawas City, Lexington, and Harbor Beach.

At Tawas City, the mean concentration of copper in water is elevated above the Agreement objective of 5 µg/L. At DeTour Passage the mean concentration of zinc approaches the level documented to be chronically toxic to certain aquatic organisms. In both cases, the source is unknown.

In sediment, zinc levels at Cheboygan and Harbor Beach exceed the U.S. EPA dredge spoil disposal guidelines. At Harbor Beach, iron and chromium levels are also elevated as a result of past operations of the Hercules Company. PCB's were detected in sediments from the Ausable and Bayfield River mouths. Although sediments at a number of U.S. locations along the Lake Huron shoreline including Alpena, Caseville, Au Sable, Hammond Bay, Harrisville, and Sebewaing had been classified as polluted, mainly because of sewage discharges from small craft and ships into the confined harbour areas, implementation of discharge regulations has resulted in reclassification of the sediment to unpolluted at all locations except Sebewaing.

Individual fish from the Goderich and the Alpena areas exhibited elevated levels of PCB's. Measurable levels of DDT have been reported in water samples from DeTour, Cheboygan, Presque Isle, and Lexington. Dieldrin has also been reported at DeTour.

Heated water discharges from the Douglas Point-Bruce Nuclear Power Development site, the largest power development and thermal discharger on the Upper Lakes, occasionally result in the Ontario guideline for temperature elevation being exceeded.

WHOLE-LAKE FACTORS

Organics and mercury are both local problems and whole-lake factors. Nutrient enrichment, a demonstrated local problem, also requires consideration from a whole-lake perspective. The local problems are often the result of point source discharges, as discussed above. The whole-lake perspective is also required since degradation has occurred or could occur throughout both Lake Huron and Lake Superior. Because these materials can persist in the water column, the circulation, mixing, and dispersal patterns of the lakes render all sources - point and nonpoint - of these materials important. Further, nonpoint inputs, such as land runoff and atmospheric deposition, can contribute a significant portion of the total input. Thus, pollution abatement measures applied to just the point-source component of these inputs may not be sufficient to restore or preserve the integrity of the open-lake ecosystem. For these whole-lake factors, for various reasons, the concept of transboundary pollution is different from when applied to specific point source discharges.

NUTRIENT ENRICHMENT (PHOSPHORUS)

Enrichment of a water body refers to the effects of nutrient inputs. These inputs can, in turn, cause increased bacterial populations, excessive algal growth, and an algal population shift to less desirable forms. For the Upper Lakes, phosphorus is the limiting nutrient for algal production. Excess phosphorus can result in excess algae, which can, in turn, result in decreases in the lake's oxygen levels, alter fish and benthos populations, increase turbidity, cause taste and odour problems in water supplies, and generally render the water less desirable for recreational use.

Limnological experience indicates that if the total phosphorus concentration in lake water is less than 10 µg/L, there should not be any serious algal blooms and consequent problems. If the concentration exceeds 20 µg/L, however, then enrichment problems will probably be present. The Reference Group confirmed that the open waters of the Upper Lakes are oligotrophic; Table 7 shows that the average total phosphorus concentration is less than 5 µg/L in the open waters of Lake Huron and Lake Superior. Substantially elevated phosphorus concentrations occur only in a number of nearshore locations in the Upper Lakes, as discussed in the preceding section of this chapter.

In short, phosphorus is generally not a whole-lake problem in the Upper Lakes, and will not become one if necessary corrective and preventive actions are implemented. There are, however, indications in the form of subtle biological shifts of approaching mesotrophy in southern Lake Huron, which receives the outflow from Saginaw Bay. Phosphorus removal programs in the Saginaw Bay Basin will not only vastly improve the Bay, as discussed above, but will also reduce the threat to the open lake.

Table 8 summarizes municipal and industrial point-source loadings and total loadings to the Upper Lakes. Only in the case of the main body of Lake Huron did point sources contribute a significant percentage (29%) of the total phosphorus loading in 1974, and much of this was via Saginaw Bay. On the U.S. side of the Upper Lakes, municipal phosphorus reduction programs were scheduled, primarily at Duluth and in the Saginaw Bay Basin. The objective of these programs, now mostly completed, was to reduce the annual phosphorus loading to Lake Superior and Lake Huron by 200 and 700 tonnes, respectively. After these scheduled reductions are achieved, the municipal and industrial point-source component to the total phosphorus loading to each of the Upper Lakes will be about 10%; nonpoint inputs (upstream feeder lakes, land runoff, and atmospheric deposition) will account for about 90% of the total phosphorus loading.

The scheduled reductions should be achieved by 1979 through a combination of factors. Construction should be complete and the remaining phosphorus removal facilities operational at Duluth, Marquette, and Flint, as discussed above. Phosphorus removal is on line at other major municipalities in the U.S. portion of the basin, but some have not achieved the target load reduction because of operational difficulties. However, in October 1977 Michigan enacted legislation to limit the phosphorus concentration in laundry detergents to 0.5% by weight. This limitation is in general resulting in lower influent and effluent phosphorus concentrations at municipal sewage treatment plants and, thus, assisting in meeting or exceeding the target load reductions.

In Canada, phosphorus removal facilities are in place at a number of municipalities on Georgian Bay, as discussed above, but operational difficulties have precluded achieving the targeted load reductions. If the desired reductions were achieved, the phosphorus loading to Georgian Bay would be reduced by about 25 t/a, based on data presented in Appendix C to the 1977 Annual Report of the Great Lakes Water Quality Board.

Phosphorus removal capability has not been installed at many municipalities on the Ontario side of the Upper Lakes Basin; the two major direct municipal dischargers without phosphorus removal capability are Thunder Bay and Sault Ste. Marie, Ontario. The Commission recognizes that each point source is a small fraction of total point source loads and, further, that point source loads to the Upper Lakes are but a small fraction of total loads. However, since these are the most readily controllable sources, they should be subjected to control.

Also based on Water Quality Board data, if all municipal dischargers in the Upper Lakes Basin effected a further reduction in the effluent concentration of phosphorus from 1.0 to 0.5 mg/L (without flow augmentation), there would be a fractional decrease in total loading to the Upper Lakes (see Table 8).

The Reference Group projected that, in the absence of whole-lake controls, phosphorus loadings to the Upper Lakes may increase by 20% to 40% by the year 2020. Much of this increase could result from population growth and from changes in land use such that higher unit loadings could result from land runoff. Changes in the various indicators of water quality, such as ambient phosphorus, chlorophyll α, and dissolved oxygen concentrations and transparency are predicted. The Vollenweider model and other assessment techniques of trophic state also predict that the open waters of the Upper Lakes would still be in the oligotrophic range, even with these increased loadings, except for certain areas of southern Lake Huron that are affected by phosphorus from Saginaw Bay. However, the Reference Group recommended that, in order to prevent degradation, no increase in controllable phosphorus inputs should be permitted on a lakewide basis. The Reference Group target loadings are shown in Table 8. The Commission agrees with this recommendation, in keeping with its nondegradation philosophy, described in Chapter 7, and which it also considers to be necessary to minimize phosphorus inputs downstream.

Based on considerations of local effects, prevention, nondegradation, and equity, the Commission concludes that a municipal phosphorus effluent limit of 1.0 mg/L should be established for all municipal and industrial dischargers, and more stringent limits should be established, where required, for local water quality. In addition, the Commission suggests that Governments require the application of best practicable technology throughout the basin to minimize inputs.

ORGANIC CONTAMINANTS

Organic pollutants constitute the most widespread waste loadings into the waters of the Upper Lakes. These may be divided into essentially three categories, although there can be some overlap, depending on the contaminant:

1) Those which degrade biologically or chemically and which result in sludge deposition and reduce oxygen levels. Municipalities and industries which handle organic matter can discharge such materials; the loading is generally reported as biochemical oxygen demand (BOD).

2) Those which can cause taste and odour problems in water supplies or taint fish. The best known are the phenols; pulp and paper mills are common sources.

3) Those which do not readily degrade and which may bioconcentrate, and which may be directly toxic to aquatic life or to consumers of aquatic life, or which may be metabolized to a more toxic form. The industrial chemical PCB and the agricultural chemical DDT are two examples of such persistent synthetic organic contaminants.

The most serious is the last category. A wide array of these persistent synthetic organic contaminants has been identified quantitatively or qualitatively in sediments and fish, where they accumulate, and occasionally at detectable levels even in the water itself. In many cases, the concentrations violate accepted or recommended criteria. Contaminants detected include PCB's, DDT and its degradation products, aldrin, dieldrin, lindane, plus a wide array of other chlorinated hydrocarbons and polynuclear aromatic hydrocarbons. The general significance of the presence of these materials in the Upper Lakes ecosystem is given below; extensive discussion of specific materials and possible sources is given in the Reference Group report.

Specific sources of introduction to the lake system have only been determined in a few cases; much of the loading appears to be from nonpoint sources. Dispersion of persistent organic contaminants throughout the lake ecosystem occurs both within the lake by circulation and mixing and through atmospheric transport. Whole-lake degradation, especially in fish, is clearly indicated.

Atmospheric inputs appear to be a significant source of persistent organic contaminants, since several of the compounds were found at comparable levels in both Lake Superior and Lake Huron. Further evidence of atmospheric transport is indicated by the presence of similar concentrations of such persistent organic compounds as PCB's, hexachlorobenzene, heptachlor epoxide, and methoxychlor in fish from Lake Superior and in fish from Siskiwit Lake, an inland lake on Isle Royale which has received no known direct discharges of these compounds.

The seriousness of the need for control of persistent organic substances within the Upper Lakes Basin is well illustrated by the Reference Group's studies on PCB's and DDT. Although DDT was banned during 1969-70 from use on the states bordering on Lake Michigan, was essentially banned in Canada in 1970, and then banned in the entire United States in 1972, by 1978 the average concentration of DDT in Lake Superior fish had not declined from levels reported for previous years. Although fish taken from Lake Superior (except large lake trout) and from Lake Huron do not contain DDT levels in excess of the current health protection guidelines of 5 mg/kg, the levels in many fish exceed the Agreement objective of 1 mg/kg, which was designed to protect fish-eating wildlife as well as human health.

The chemistry of the water mass itself is probably responsible for the persistence of the current levels of DDT residues, particularly DDE, in Lake Superior. One mechanism for removal of such organic compounds from the water column is by sorption onto suspended particles in the water; these particles eventually settle to the bottom of the lake. However, in Lake Superior, there is very little suspended material and, therefore, organic substances such as DDT are only slowly removed from the water column by this means.

Regardless of the absolute concentrations of this wide array of chlorinated hydrocarbons found in water and biota of the Upper Lakes, the Commission is concerned over the common presence of numerous toxic organics whose individual effects, acute or chronic, toxic or sublethal, are poorly known and whose potential combined effects are completely unknown both in the aquatic biota and in organisms which depend on them for food. It is apparent that both Lakes Superior and Huron are being contaminated with persistent toxic organic compounds from essentially unknown sources. Past efforts to control DDT contamination, although effective in Lake Michigan, appear to have had little effect as yet in Lake Superior. Further contamination of the biota by PCB's and, to a lesser degree, dieldrin is still considered unavoidable in the Upper Lakes.

In summary, persistent synthetic organic contaminants are found in sediment and fish. Little is known about their chemical and biological movement and their fate in the environment. In addition, there is a real potential that if pollution by toxic organics continues unchecked, human consumption of fish may be precluded, and the usefulness of the fisheries may therefore be lost. In the extreme, the continued survival of the fish themselves may be in doubt. Since it is difficult to prevent the entry of these chemicals, both directly and indirectly, into the water, strict regulation of their manufacture, distribution, and use is necessary. The only answer is a total ban on the discharge of such chemicals into the environment until it has been conclusively proven that these materials are safe.

METALS

Chronic exposure to metal concentrations lower than the lethal level can have serious, subtle, adverse effects on the biota. Metals taken up directly from water or through the food chain may accumulate in tissues and organs, causing growth or reproduction problems. Indirectly, metals may weaken organisms or change their behavioral patterns, making them more vulnerable to other environmental stresses such as diseases or predation. Another indirect influence is the elimination or reduction in abundance of important food chain organisms. Finally, biomagnification of metals in fish tissue may be sufficiently high to represent a hazard to wildlife and humans through consumption of contaminated fish.

Concentrations of metals in sediments are of concern because heavy metals accumulate in sediments, and chemical, mechanical, and biological activity can cause resolubilization and mobilization. Methylation, a biological process that occurs in aquatic systems, can cause transport and cycling of certain metals. An example of this is the methylation of mercury which permits the uptake of mercury by biological systems, resulting in biomagnification in fish to levels hazardous for human consumption. Methylation of other elements in the aquatic environment, such as lead, selenium, and arsenic has also been demonstrated, although there is no proof that these other metals constitute a danger to human health in the Upper Lakes at the present time.

Localized high concentrations of metals are noted in water, sediment, and/or fish in a number of nearshore areas of the Upper Lakes, especially for Lake Superior as discussed above. Abnormally high levels of copper have occasionally been found in central Lake Huron in excess of the Agreement objective, for no apparent reason.

Mercury is the only metal which is a whole-lake problem. Mercury is found in fish at levels which approach or exceed the health protection guideline of 5 mg/kg. While point source discharges and their residual deposits appear to be a contributing factor for the high levels of mercury in fish, a significant portion of the mercury input to the Upper Lakes is from natural sources, substantiated by the elevated mercury levels in walleye from Siskiwit Lake on Isle Royale, which has received no inputs of mercury other than from weathering of soil or possibly from atmospheric inputs.

Because the mineralogy of the Lake Superior, North Channel, Georgian Bay, and the northern Lake Huron Basins is generally high in concentrations of heavy metals and because there is inadequate knowledge about the health effects of these natural levels presently found in sediments, the Commission is of the opinion that heavy metals levels should not be allowed to increase, unless reasonable reassurance as to the possible significance is available. Under no circumstances should there be any discharge of mercury as a result of human activity.

DEGRADATION FROM ATMOSPHERIC INPUTS

As indicated previously, the Reference Group established that air pollution has a significant effect on the water quality of the Upper Lakes. The atmosphere is a major pathway of deleterious inputs. Airborne particulates and gases can enter the lake water through atmospheric precipitation washout (rainfall and snow) and by deposition (dustfall).

The atmosphere is a major contributor of phosphorus, heavy metals, persistent synthetic organics, and acid to the waters of the Upper Lakes. These materials enter the atmosphere from both natural and human sources, but the latter is probably dominant. The Reference Group also demonstrated that not only local but also distant emissions affect water quality; transport distances can be thousands of kilometres.

The Upper Lakes Reference Group reported that atmospheric inputs make up about 19% of the total phosphorus load to Lake Superior and about 11% of the load to Lake Huron; PLUARG, which had a more extensive data base, reported even higher phosphorus contributions from the atmosphere. Atmospheric loadings of lead and copper are estimated by the Upper Lakes Reference Group to be 30-40% of the total input. Atmospheric sulphate is a measure of the potential for acid rain; about 16% of the sulphate enters Lake Huron from the atmosphere; for Lake Superior, the value is about 29%. The effects of atmospheric discharges of sulphate on the drainage basin of Georgian Bay in the Sudbury area are well known and early effects have also been detected in the nearshore water of Georgian Bay.

Many highly stable organic contaminants have been qualitatively identified in precipitation in the Great Lakes Basin. These include PCB's, α and γ isomers of lindane, DDT and its metabolites, hexachlorobenzene, methoxychlor, chlordane, endosulfan, and dieldrin. Although the concentrations are extremely low, they can indicate very significant loadings. For example, for PCB's, although the concentration detected (0.02 µg/L) in precipitation is low, the estimated atmospheric loading of PCB's to Lake Huron is approximately one tonne per year.

Sources of atmospheric inputs to the Upper Lakes include such diverse activities as domestic, industrial, and agricultural land use. Loading to the atmosphere will increase, in general, with economic growth. Shifts in economic factors, such as increased use of fossil fuels and the introduction or withdrawal from use of synthetic organics, such as PCB's and DDT, will significantly influence loadings.

Atmospheric inputs are disproportionately significant. They directly enter the euphotic zone of the lakes and are immediately available to the biological community, while tributary inputs are available to much of the productive system only after diffusion and mixing. Hence atmospheric inputs are more available to the open lake waters.

Because of their relative importance in the Upper Lakes, atmospheric inputs of the materials cited, especially the persistent synthetic organic contaminants, must be reduced or eliminated just as much as or more than point-source and land-runoff discharges into the water.

OTHER ISSUES

Although vessel wastes, spills, and thermal inputs are also causing or likely to cause degradation of the Upper Lakes, especially in localized areas, these issues have much less impact than the other issues discussed above. Vessel wastes are of concern due to the localized impacts on harbours and the possible import of chloride and foreign biota to the lakes. Spills always have an adverse environmental impact, although the long-term effects are not well documented; it is equally important to have an effective program for spill prevention as for spill response. Thermal discharges can alter the nearshore ecosystem and the cooling water intakes can result in the entrainment of fish and fish larvae.

Other than a violation of the drinking water supply criterion for radium at Serpent Harbour on the North Channel, inputs of radioactivity have not had a deleterious effect on the water quality of the Upper Lakes. The major man-made source of radioactivity to the waters of the Upper Lakes is fallout from the atmospheric testing of nuclear weapons; the contribution from nuclear power plants is small. Total inputs of radioactivity from all sources, including natural inputs, are not expected to result in a violation of the Agreement objective, except at Serpent Harbour, where the need for additional control programs is being assessed.

The Commission is concerned, however, about contributions which may arise from the storage and disposal of spent nuclear fuel and from fuel reprocessing operations. The Commission has referred this question to the Radioactivity Subcommittee of its Great Lakes Water Quality Board for further study.

6. ANSWERS TO THE REFERENCE QUESTIONS

REFERENCE QUESTION 1

> Are the waters of Lake Superior and Lake Huron being polluted on either side of the boundary to an extent (a) which is causing or is likely to cause injury to health or property on the other side of the boundary; or (b) which is causing, or likely to cause, a degradation of existing levels of water quality in these two lakes or in downstream portions of the Great Lakes System?

The only instance of transboundary pollution from a point source discharge in the Upper Lakes occurs in the St. Marys River and the Lake George area, where phenols discharged from Algoma Steel Corporation and from the municipal wastewater treatment plant in Sault Ste. Marie, Ontario exceed the Agreement objective in U.S. waters.

There are, however, many instances where point-source discharges, often in conjunction with nonpoint inputs, are causing or are likely to contribute to pollution or degradation of existing water quality in Lake Superior and in Lake Huron. These include, most importantly, persistent toxic organics, mercury, and, in local areas, other metals and phosphorus. These are likely to cause injury to health or property on the other side of the boundary unless remedial or preventive action is taken. However, degradation of downstream portions of the Great Lakes System probably will not occur.

REFERENCE QUESTION 2

> If the foregoing questions are answered in the affirmative to what extent, by what causes, and in what localities is such pollution taking place?

The Reference Group identified numerous municipalities and industries discharging into the areas of reported pollution or degradation of the Upper Lakes. These point source dischargers and the specific receiving waters were identified in Tables 5 and 6 for Lake Superior and Lake Huron, respectively.

Most dischargers are in compliance with effluent discharge regulations promulgated by the appropriate jurisdiction. However, some of them are directly responsible for violations of Agreement objectives or jurisdictional values. The observed pollution or degradation can be the result of a number of contributing factors:

1. Installation of remedial measures has not been adequate to correct identified pollution problems or to keep pace with expansion, such as at Algoma Steel Corporation at Sault Ste. Marie, Ontario.

2. The pollution control equipment or facilities may be in place but are experiencing operational difficulties, such as for phosphorus removal at some of the municipal sewage treatment plants in the Saginaw Bay Basin and along southern Georgian Bay.

3. The pollution or degradation is residual, due to past discharges which are now controlled or which have ceased, such as the presence of mercury in fish and sediment in the Thunder Bay area.

4. Nonpoint inputs, such as from land runoff, may reinforce the point-source inputs, as is the case of phosphorus loadings in the Saginaw Bay Basin.

5. The assimilative capacity of the receiving water has been exceeded because of the number of discharges, the total quantity of waste discharged, and/or because of the natural water-exchange characteristics of the receiving water with the adjacent portion of the lake, such as for Saginaw Bay.

The relative importance of these factors varies with the location under consideration. The extent to which identified dischargers contribute to observed pollution or degradation is discussed in detail in the Reference Group's report. Chapter 5 of this report highlights the problems, the most significant sources, and the status of the required remedial programs. Some information about the present status of each point source discharger is given in the 1977 Annual Report of the Great Lakes Water Quality Board.

REFERENCE QUESTION 3

> If the Commission should find that pollution of the character just referred to is taking place, what remedial measures would, in its judgement, be most practicable to restore and protect the quality of the waters, and what would be the probable cost?

To abate existing point-source pollution, where pollution is defined as a violation of an objective or some jurisdictional value, remedial measures are required for the municipal and industrial dischargers named in Table 9.

The Reference Group was unable to address the question of costs in detail. The Reference Group did, however, compile a summary (Table 10) of capital costs for municipal waste collection and stream discharge treatment facilities for collectors, land acquisition, engineering, and twenty-year treatment plant design capacity. This did not include sewer extensions for new development, operating costs, or alternative treatment or disposal methods. The Reference Group also provided cost estimates for industrial control, based on best practicable waste treatment technology in each country; the estimate also includes $300 million for an on-land disposal site for mine tailings from Reserve Mining Company. Increased water recycling and modification of manufacturing processes to use less water and to minimize product and by-product losses may reduce the estimated industrial costs. In general, the validity of all these cost estimates may be regarded as an order of magnitude.

TABLE 9

Municipal and Industrial Dischargers for which Remedial Programs are Recommended

ISSUE	MUNICIPALITY OR INDUSTRY AND LOCATION
Municipal or Industrial Phosphorus Reduction	Lake Superior - Duluth-Superior Harbor Marquette Munising Ontonagon Thunder Bay Jackfish Bay Nipigon Bay Lake Huron - Alpena Cheboygan Goderich Harbor Beach Penetang Midland Tobermory Owen Sound Collingwood Parry Sound Saginaw Bay Basin (all upstream dischargers) Sault Ste. Marie, Ontario
Bacterial Reduction	Lake Superior - Black River Duluth-Superior Harbor Jackfish Bay Marathon (Peninsula Harbour) Munising Ontonagon Red Rock (Nipigon Bay) Thunder Bay Lake Huron - Alpena Blind River Cheboygan Goderich Harbor Beach Owen Sound Penetang Saginaw River Mouth Sault Ste. Marie, Ontario Spanish River Mouth Tawas City
Metals Reduction	American Can of Canada Ltd., Marathon (mercury) Algoma Steel, Sault Ste. Marie, Ontario (iron and zinc) Collingwood (zinc, cadmium, lead) Saginaw Bay Basin (all upstream dischargers)
Taste and Odour Compounds	Great Lakes Paper Co., Thunder Bay American Can of Canada Ltd., Marathon Kimberley Clark of Canada Ltd., Terrace Bay Eddy Forest Products, Espanola Algoma Steel, Sault Ste. Marie, Ontario
Asbestos	Reserve Mining Co., Silver Bay
Radioactivity	Serpent Harbour (upstream sources)

a. Disinfection for bacterial reduction, in order to protect public health, may be limited to seasonal implementation.

TABLE 10

ESTIMATED CAPITAL COSTS FOR WASTE TREATMENT[a]

BASIN	MUNICIPAL	INDUSTRIAL	TOTAL
LAKE HURON			
United States	124,000,000	86,000,000	210,000,000
Canada	31,000,000	48,000,000	79,000,000
LAKE SUPERIOR			
United States	71,000,000	323,000,000	394,000,000
Canada	48,000,000	144,000,000	192,000,000
TOTALS			
United States	195,000,000	409,000,000	604,000,000
Canada	79,000,000	192,000,000	271,000,000

a. 1973 dollars

Although installation of the identified remedial measures should restore water quality to within accepted values for the issues of concern for most impacted areas, population growth, additional industrial development, and nonpoint inputs will require the application of more stringent municipal and industrial source abatement to protect water quality for the future.

In many cases, the responsible jurisdictions have already completed implementation of the necessary remedial measures to correct the problems identified in Table 9 and to bring municipal and industrial discharges into compliance with jurisdictional or Agreement objectives. In other cases, these remedial programs are in the planning or construction stages.

To reduce the phosphorus loading from all plants in the Canadian portion of the Upper Lakes Basin to 1.0 mg/L would require an estimated capital expenditure of $2,000,000 in addition to that given in Table 10. The costs in Table 10 include the costs to reduce phosphorus in United States municipal discharges to 1.0 mg/L.

These projections are based on achieving a reduction in loadings to meet the 1978 Water Quality Agreement objectives and would not restore the water quality of these areas beyond the objective levels, much less to the quality that obtained prior to human activity. It assumes no increases in inputs. Further improvements beyond this level would require the utilization of alternative treatment methodology, such as land application of wastes, to minimize phosphorus inputs, accompanied by metal and toxics removal, where necessary, to avoid contamination of ground waters. Even with these measures, however, some limitation on growth may be required.

In the U.S. the capital cost of the present program to contain polluted dredge spoil is estimated at $59,600,000 for Lake Huron and $4,300,000 for Lake Superior. There is very little dredging of Upper Lakes harbours in Canada, but where contaminated materials are encountered, the spoils are generally incorporated into landfill operations utilizing existing containment areas. No costs are presently available for a permanent dredging disposal area at Thunder Bay.

When a storm overloads the system, storm and combined sewer water bypasses the wastewater treatment plant. Such overflows can contribute large loadings of phosphorus, bacteria, and other wastes directly to the receiving water. Preliminary studies in both countries show that the capital costs of programs to eliminate combined sewers in the U.S. is estimated at $130,000,000 for Lake Huron and $30,000,000 for Lake Superior. Similar costs for Canada have been estimated at $150,000,000 for Lake Huron and $25,000,000 for Lake Superior.

Costs for vessel waste treatment and control may be large for individual vessel operators but are a relatively small part of the total cost picture. Similarly, costs of measures for spill prevention and control are usually small in comparison with the other costs for pollution control and are often more concerned with operational procedures than with capital costs.

Further cost estimates for the control of inputs from point and nonpoint sources will be available in the Commission's report on the study conducted by the Pollution from Land Use Activities Reference Group.

REFERENCE QUESTION 4

> In the event that the Commission should find that little or no pollution of the character referred to is taking place at the present time, what preventive measures would, in its judgement, be most practicable to ensure that such pollution does not occur in the future and what would be the probable cost?

The two major threats facing the Upper Lakes are localized enrichment from phosphorus and lake-wide persistence of synthetic organic compounds. Nonpoint inputs are major contributors, to which conventional point source remedial measures cannot be applied.

PHOSPHORUS

Based on considerations of prevention, nondegradation, and equity, the Commission concludes that a municipal phosphorus effluent limit of 1.0 mg/L should be established for all municipal and industrial dischargers, and more stringent limits should be established, where required, for local water quality. On a whole-lake basis, control of nonpoint sources of phosphorus is not justified.

Phosphorus reduction programs for Lake Huron and Lake Superior are needed to restore, preserve, and protect the immediate receiving water. The specific phosphorus control measures to be implemented depend on the specific receiving water and could take the form of more stringent point source effluent limitations or nonpoint land runoff control, or some combination. Alternative treatment methodologies, such as land application, should be considered to reduce loadings. The discussion provided in Chapter 5 for phosphorus in Duluth-Superior Harbor, the nearshore and embayment areas of southern Georgian Bay, and Saginaw Bay amply illustrate the advantage of a comprehensive management strategy.

PERSISTENT SYNTHETIC ORGANIC COMPOUNDS

For many persistent synthetic organic compounds, laboratory studies have persuasively demonstrated toxicity and other harmful effects at elevated doses. It is also true, however, that there exists only limited knowledge about the effects of these compounds at the concentrations detected in the Upper Lakes ecosystem, or of other compounds presently in use but not yet detected in the environment. The reason is that present toxicity testing procedures for environmental and human health effects for ambient concentrations are expensive, time consuming, and scientifically inconclusive. The problem is further complicated by the persistence of these materials and the irreversibility of their effects. In these circumstances, the Commission believes that responsible prudence requires that human and environmental exposure to these compounds must be prevented as far as possible until safe levels, if they exist, are determined.

If these materials are allowed to escape into the environment, their concentrations in the atmosphere or in land runoff are too low to permit effective control. In addition, specific point source inputs have generally not been identified. The solution, then, in order to prevent pollution or permanent degradation of the Upper Lakes and its biota, is to strictly regulate the manufacture, sale, transport, and use of these compounds, and to totally ban their discharge into the environment. PCB's, PBB's, aldrin, dieldrin, and DDT are such materials; however, because their high toxicity has been demonstrated and because their uses are such that escape into the environment is probable, if they are used, even strict regulation is not sufficient. These materials must be completely banned from manufacture, transport, and use. The economic disruption of banning these materials can be costly, and transition to alternative materials can take years, but such measures are necessary until safe levels, if they exist, are determined.

Procedures are presently being developed to predict which compounds, either presently in use or being considered for use, could be deleterious to the Upper Lakes ecosystem. Physical, chemical, and toxicological data on as many compounds as possible are being compiled. Predictive methodology is presently being developed wherein the bioaccumulation potential of a compound can be estimated. In addition, the activity of a compound can be estimated by comparing functional groups (component parts) of the new compound with a compound having similar component parts for which activity is known.

A more general response to Reference Question 4 is set forth in Chapter 7, as a policy of nondegradation.

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A more general response to Reference Question A is set forth in Chapter 7 as a policy of nondegradation.

7. NONDEGRADATION

Reference Question 4 and the description of the Upper Lakes given in the preceding chapters logically lead to the need for a preservation and management philosophy for waters whose quality is better than the Agreement objectives or jurisdictional values, in order to maintain these waters at their present high quality. In further response to Reference Question 4, this chapter describes a nondegradation policy for the Upper Lakes.

FRAMEWORK FOR WATER QUALITY PRESERVATION

It is necessary at the outset, when establishing a water quality policy, to set out water quality objectives and to categorize water quality in relation to them. The Reference Group classified the waters of the Upper Lakes as non-degraded, degraded, or polluted in relation to both the 1972 and the proposed 1978 Agreement objectives. In this classification, non-degraded water is high quality water which shows no significant change as a result of human activity, and its uses are not limited. Degraded water shows the effects of human activity that may result in occasional marginal violations of water quality objectives but which would generally permit the most sensitive water uses. Polluted water shows frequent or severe violations of water quality objectives, and some or all uses would be substantially limited.

The Commission noted that under both the 1972 and the 1978 Water Quality Agreements, specific water quality objectives have been adopted as "minimum desired levels of water quality", with the general objective of protecting all present and future water uses. (It should be noted that the adequacy of the Agreement objectives must be periodically reexamined in the light of emerging knowledge. Little is known, for example, about the interrelationship of certain substances, and the existing objectives do not reflect such relationships.) The Commission reads these objectives as essentially synonymous with the Reference Group's "degraded" classification.

Where water quality does not meet the objectives, the Agreement dictates that remedial programs be defined and implemented. To address this provision, water quality conditions and concentrations of pollutants or contaminants in sediment, fish, and aquatic life must be compared with these objectives. This well understood management process is being utilized in response to those instances of pollution in the Upper Lakes described in Chapters 5 and 6. Through implementation of recommended remedial measures, improvement in water quality can be expected.

Although the Reference Group's study has shown that localized violations of water quality objectives occur, for which remedial programs are needed, the Commission concludes that, overall, the waters of Lake Superior and Lake Huron remain of high quality and that, in general, the waters are not polluted and the biological community is healthy. Generally, the water quality is better than that prescribed by the water quality objectives given in the 1978 Agreement, and is also better than the values given in present jurisdictional standards, criteria, and guidelines.

Anticipating that this conclusion might be reached, the Governments made their intent clear in the 1978 Agreement, to recognize the need to maintain such existing high-quality water, by the following provision:

> Notwithstanding the adoption of Specific Objectives, all reasonable and practicable measures shall be taken to maintain or improve the existing water quality in those areas of the boundary waters of the Great Lakes System where such water quality is better than that prescribed by the Specific Objectives, and in those areas having outstanding natural resource value.

The Commission concurs with this provision and believes that water quality management in the Upper Lakes must be predicated on maintaining the present high quality of the water and, as far as possible, enhancing such quality rather than responding only to identified problems. However, consistent with the provision that "all reasonable and practicable measures shall be taken", the Commission concludes that nondegradation does not mean the prohibition of inputs of all substances which may be considered to degrade water quality from natural conditions. The Commission believes, however, that any inputs must be rigidly assessed and controlled to ensure that they are readily degradable, are non-toxic, do not pose any long-term sub-lethal danger, are non-accumulative in biota, and whose effects on the lakes are not irreversible. Where doubt exists as the effects which a discharge may exert, and a reasonable analysis indicates the need for caution, Governments are urged to take the prudent course in applying these limitations. Further, the Commission emphasizes that in no case should such inputs violate the general or specific water quality objectives set out in the 1978 Agreement.

With the adoption of these limitations as unalterable conditions to be met in the Upper Lakes, the Commission believes that the preservation of all functional water values, present and future, can be realized, consistent with the nondegradation policy as reflected by Governments in the 1978 Agreement.

It is the Commission's view that the adoption of the foregoing conditions or principles, to be observed in the implementation of water quality management practices, is mandatory because of the risks associated with many substances discharged into the Upper Lakes System:

1. Many pollutants (e.g. persistent synthetic organic compounds) have demonstrable adverse health and environmental effects at concentrations higher than those found in the waters of the Upper Lakes; however, the effects at both the present rates of input and the concentrations presently found in the ecosystem are not known.

2. Some substances may bioaccumulate in fish and could also result in increased human health and environmental hazards.

3. For some materials (e.g. metals in sediments) natural baseline levels are higher than levels found in other lakes.

4. The full effects of waste inputs on nearshore water quality are not understood.

5. The effects of changes in nearshore water quality on open water quality are not known because nearshore/offshore exchange processes are not defined.

6. The Upper Lakes may not be in equilibrium with present waste loadings; this lag in response time means that the potential consequences of a discharge will not become known immediately and irreversible damage may occur.

7. Conservative management is required because assessments are often based on average conditions; seasonal or geographic conditions may mean that maximum concentrations are considerably different from the stated average.

ACHIEVEMENT OF NONDEGRADATION

The Commission concludes that nondegradation, as defined and limited above, can be achieved while accommodating population growth and economic development. However, to ensure that the principles of nondegradation are not violated, careful consideration will have to be given to the nature and quantity of each substance to be discharged, its pathways to and in the water, and the concentrations and quantities currently present.

For pollutants which reach the water from point-source municipal and industrial discharges, the Commission endorses the concept of zero point-source discharge as an ultimate goal. The Commission believes it important, for the long-run preservation of the unique values of the Upper Lakes, that this goal be constantly a guiding principle so that any point sources are seen as deviations to be eliminated in the long term and minimized in the short term. The Commission recognizes the difficulty or, indeed, the impracticability of achieving this goal in the short term, considering the limitations of present waste treatment and control technology. These limitations notwithstanding, the Commission believes that in waters of a quality better than the objective level, nondegradation, as described in the foregoing, can be achieved and at the same time ensure that the measures taken are "reasonable and practicable", through the application of an offset policy. An offset policy would permit growth without adverse effect on water quality by maintaining or decreasing the net input of pollutants to the affected receiving water through a reduction of the amounts presently being discharged. In framing this concept, the Commission has not addressed the question of load allocations among jurisdictions. The result would be similar to the Reference Group's recommendation that there be no net increase of phosphorus input to the Upper Lakes.

This offset policy would only apply to those substances which are biodegradable, non-toxic, and non-cumulative. With respect to phosphorus, although build-up of phosphorus will occur in sediments, there is a vast margin in the open lakes before increases would cause any problems. Therefore, the Commission recommends that jurisdictions applying best practicable technology, as it develops, to phosphorus removal be permitted offset reductions below target levels to accommodate new growth and development. These offset reductions could be achieved through the development of alternative production processes or through the application of more effective waste treatment and control technology. The policy, in any case, would permit future discharges only to the extent of the capacity of the receiving waters to accommodate such discharges without altering existing water quality.

It must be clearly understood that for toxic and hazardous materials, such as PCB's, DDT, and mercury, nondegradation can only be achieved by allowing no discharge to the environment. For such persistent materials which only slowly degrade, which bioaccumulate, or whose fate in the ecosystem is unknown, the ability of the receiving water to assimilate the pollutant is relatively low and effects from the discharge could, in the extreme, be irreversible. For those persistent toxic substances, the only way to avoid degradation is to completely prohibit their entry into the water system, insofar as inputs can be determined. Manufacture, distribution, and use of these materials must be carefully monitored to prevent their escape into the environment.

The goal is to achieve a minimum discharge of municipal and industrial waste to the environment through the use of best available technology.

This discussion does not deal with areas presently in violation of Water Quality Agreement objectives. The Commission's recommendations to bring these areas into compliance is provided in the answer to Reference Question 3. The Commission recommends that Governments decide whether they wish to achieve and maintain a water quality higher than the objectives in these areas. The non-degradation policy stated above can be implemented in those areas when the levels so determined have been achieved.

EDUCATION AND PUBLIC ATTITUDES

To better ensure that the present high quality of the Upper Lakes will be maintained, changes in attitudes and perceptions about our environment as a fragile, non-recoverable resource must occur at all levels of society. The vehicles to accomplish this are education and public involvement.

Both short- and long-term education programs are required to both enlighten and change traditional concepts or misconceptions about the environment. A sustained, adequately funded, multi-level program must be encouraged. Schools can keep such a program going; other organizations can maintain the interest of those reached.

The intent of this educational process is, then, to reach the various segments of society and to create an awareness. An informed public would be able to better assess the consequences of alternative decisions, make value judgments, and reach a consensus about what can or should be achieved to satisfy the majority social interests. Society as a whole must be involved in the planning and decision-making processes, not just those segments with a visible vested interest.

In the hearing process, the Commission found a public perception that industrial attitudes toward the environment range from a belief in the right to pollute to that of exerting maximum efforts to minimize environmental effects. The former public view was considered more evident in the Upper Lakes Basin. Although many industries are striving toward a genuine good-corporate-citizen image within the present systems, a more positive interface with both government and the public is required, perhaps with more visibility for industry's environmental activities.

TECHNOLOGICAL DEVELOPMENT

A significant effort must be made by all sectors of society to develop new and innovative production, treatment, and waste disposal or recovery technologies, if there is to be continued economic and population growth in the Upper Lakes Basin while simultaneously meeting the goal of maintaining the existing water quality of the lakes. The Reference Group reported that with the application of new technology the estimated future investments in treatment plants and equipment may not be greater than existing levels and that loadings might actually decrease.

The Commission perceives the role of the Governments to be one of encouraging and coordinating development and implementation of these measures. Governments are in a positon to influence technological development by providing subsidies or tax incentives, setting strict effluent limitations, and requiring or encouraging resource recovery and recycling.

INFORMATION REQUIREMENTS

Lack of scientific knowledge about the Upper Lakes System may be the limiting factor in many instances for maintaining the integrity of the ecosystem. The Reference Group noted, and the Commission concurs, that there are many gaps in the understanding of the Upper Lakes System. If properly addressed, research efforts would provide essential information for proper management of the lakes. Areas requiring further study are summarized below.

A greater understanding is required of the effects of mixtures of compounds, whether synergistic, additive, or antagonistic. Furthermore, the ecological and health effects of the synthetic organic compounds identified by the Reference Group in Upper Lakes fish should be determined. Mechanisms to predict which substances have the potential to be harmful to man and the environment need to be developed.

Water quality models need to be developed and nearshore/offshore exchange processes understood for the Upper Lakes, in order to better and more efficiently predict their capacities to assimilate nutrients, organics, and metals; and in order to understand and project changes in the ecosystem quality with changes in loading, population, economic growth, production and treatment technology, and public and legislative attitudes.

The impact of sediment-associated contaminants on water quality and on biota requires additional investigation.

There is a need to refine present municipal, industrial, erosion, tributary, and atmospheric loading estimates, and to maintain intensive monitoring of major inputs to nearshore areas, so that increases in loading can be quickly identified as to source, and measures to reduce the inputs implemented where necessary.

8. RECOMMENDATIONS

The Reference Group made a number of recommendations to the Commission; these are included as Appendix D to this report.

Based on its consideration of the Reference Group's report and recommendations, and the Commission's public hearings, in response to the Reference dated April 15, 1972, from the Governments of Canada and the United States, the International Joint Commission recommends that:

1. To correct the point-source pollution problems identified in this report and summarized in Table 9, and to achieve water quality objectives, appropriate remedial measures be implemented as soon as possible.

2. Surveillance be maintained to assess the receiving waters and the open waters of the Upper Lakes in order to determine trends in, and to ensure protection of the water quality of the Upper Lakes.

3. Where sources of pollution have not been identified, the Governments undertake the necessary investigative studies, and develop and implement remedial measures.

4. The Governments adopt as policy for Lake Huron and Lake Superior the philosophy of nondegradation proposed by the Commission. Inherent in the adoption of this policy to achieve the goals of nondegradation is the obligation to: develop the scientific and technical information base required for proper management; encourage development of new and innovative manufacturing and waste treatment technology; encourage public education and involvement in long-range planning and in the decision-making process; and encourage industrial participation.

5. To restore degraded areas of the Upper Lakes to a more desirable trophic state and to prevent potential future problems, phosphorus loadings be reduced by reducing the phosphorus concentration in all municipal and industrial discharges to 1.0 mg/L and lower where local conditions require, and by limiting the allowable phosphorus content of all detergents to not more than 0.5% phosphorus by weight.

6. To maintain desirable water quality in the Upper Lakes and to achieve nondegradation, while accommodating growth and development, the Governments should consider an offset policy which would require more stringent point source controls to ensure that loadings from point sources do not increase with growth. Further, Governments should apply such measures to control pollution from nonpoint land sources as shall appear in the Commission's forthcoming report on the study conducted by the Pollution from Land Use Activities Reference Group.

7. For the particular metals in the locations cited in this report as exhibiting high concentrations in either the water, sediment, or fish, no further inputs be allowed to those areas unless the discharger can show no consequences to health and property.

8. To protect human health and aquatic life, and to achieve nondegradation, the Governments ban the manufacture, sale, transport, and use of PCB's, PBB's, aldrin, dieldrin, DDT and its derivatives, and all other persistent synthetic organic compounds with known highly toxic effects, the use of which will result in their entry into the environment. The manufacture, sale, transport, and use of all other persistent synthetic organic compounds with known deleterious effects be strictly regulated to prevent their entry into the environment.

9. Predictive methodology be developed and applied to determine the health and environmental effects of other compounds presently in use or detected in the ecosystem, and the uses of such compounds minimized, pending such determination. Furthermore, the introduction of new compounds not be approved until the producer demonstrates that such compounds will not harm man or the environment. To enhance the efficiency of the process and in light of the mobility of the substances, the Governments should establish a cooperative testing and evaluation program and mutually agreeable standards for determining toxicity.

10. Governments address the issue of the effects of the atmosphere on the water quality of the Great Lakes. Consideration should be given to sources, composition, transport, deposition, and effects of atmospheric constituents on the Great Lakes and its watershed. Emphasis should be placed on nutrients, metals, synthetic organic compounds, and acid.

11. Governments complete research into the effects of asbestos fibre size, shape, and concentration on all biological forms in the Upper Lakes, especially when ingested by man. A drinking water standard for asbestos should be established as soon as possible.

12. Governments provide post-spill monitoring to determine the nature and character of the material spilled and the long-term environmental effects of the spills and cleanup operations, and to improve response measures and recovery technology.

13. Comprehensive environmental assessment studies be conducted for thermal discharges to the Upper Lakes.

14. Particular emphasis be given to the design and location of water intake and discharge structures to minimize the entrainment of fish and fish larvae.

15. Governments expedite their consideration of the development of compatible regulations for the control of spills and discharges from vessels, in keeping with the provisions of Annexes 4 and 5 of the 1978 Water Quality Agreement.

APPENDIX A

TEXT OF REFERENCE TO THE INTERNATIONAL JOINT COMMISSION TO STUDY POLLUTION PROBLEMS OF LAKE HURON AND LAKE SUPERIOR

I have the honour to inform you that the Governments of the United States of America and Canada, pursuant to Article IX of the Boundary Waters Treaty of 1909, have agreed to request the International Joint Commission to conduct a study of water quality in Lake Huron and Lake Superior, in the light of the provision of Article IV of the Treaty which provides that the boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health and property on the other side, and in the light also of the Great Lakes Water Quality Agreement signed on this date. This reference represents the response of the two Governments to recommendation No. 20 of the Commission in its final report dated December 9, 1970, on pollution of Lake Erie, Lake Ontario, and the International Section of the St. Lawrence River.

The Commission is requested to enquire into and to report to the two Governments upon the following questions:

(1) Are the waters of Lake Superior and Lake Huron being polluted on either side of the boundary to an extent (a) which is causing or is likely to cause injury to health or property on the other side of the boundary; or (b) which is causing, or likely to cause, a degradation of existing levels of water quality in these two lakes or in downstream portions of the Great Lakes System?

(2) If the foregoing questions are answered in the affirmative, to what extent, by what causes, and in what localities is such pollution taking place?

(3) If the Commission should find that pollution of the character just referred to is taking place, what remedial measures would, in its judgement, be most practicable to restore and protect the quality of the waters, and what would be the probable cost?

(4) In the event that the Commission should find that little or no pollution of the character referred to is taking place at the present time, what preventive measures would, in its judgement, be most practicable to ensure that such pollution does not occur in the future and what would be the probable cost?

The Governments would welcome the recommendations of the Commission with respect to the general and specific water quality objectives that should be established for these lakes, and the programs and measures that are required in the two countries in order to achieve and maintain these water quality objectives.

The Commission should submit its report and recommendations to the two Governments as soon as possible and should submit reports from time to time on the progress of its investigation.

In the conduct of its investigation, the Commission is requested to include consideration of pollution entering Lake Huron and Lake Superior from tributary waters, including Lake Michigan, which affects water quality in the two lakes, and to enquire into and report on the upstream sources of such pollution. The Commission may utilize the services of qualified persons and other resources made available by water management agencies in Canada and the United States and should as far as possible make use of information and technical data heretofore acquired or which may become available during the course of the investigation, including information and data acquired by the Commission in the course of its investigations and surveillance activities conducted on the lower Great Lakes and in the connecting channels.

In conducting its investigation, the Commission should utilize the services of the international board structure provided for in Article VII of the Great Lakes Water Quality Agreement.

APPENDIX B

MEMBERSHIP OF THE UPPER LAKES REFERENCE GROUP AND ITS COMMITTEES

The International Joint Commission appointed the Upper Lakes Reference Group in November 1972. When the Reference Group submitted its report to the Commission in July 1976, the membership of the Reference Group consisted of the following:

UPPER LAKES REFERENCE GROUP

UNITED STATES MEMBERS

C. M. Timm, Director, Surveillance and Analysis Division, U.S. Environmental Protection Agency, Region V, U.S. Chairman.

L. J. Breimhurst, Director, Division of Water Quality, Minnesota Pollution Control Agency.

Dr. J. F. Carr, National Marine Fisheries Service, National Oceanic and Atmospheric Administration.

W. E. McCracken, Chief, Comprehensive Studies Section, Michigan Department of Natural Resources.

F. H. Schraufnagel, Director, Bureau of Standards and Surveys, Wisconsin Department of Natural Resources.

N. A. Thomas, Chief, Large Lakes Program, U.S. Environmental Protection Agency.

W. A. Willford, Great Lakes Fishery Laboratory, U.S. Fish and Wildlife Service.

CANADIAN MEMBERS

Dr. G. K. Rodgers, Chief, Applied Research Division, Canada Centre for Inland Waters, Canada Department of the Environment, Canadian Chairman.

R. M. Gale, Inland Waters Directorate, Canada Department of the Environment.

J. D. Kinkead, Head, Great Lakes Surveys Unit, Ontario Ministry of the Environment.

A. H. Lawrie, Fish and Wildlife Research Branch, Ontario Ministry of Natural Resources.

Dr. K. Patalas, Freshwater Institute, Canada Department of the Environment.

S. E. Salbach, Supervisor, Planning and Coordination Section, Ontario Ministry of the Environment.

G. L. Van Fleet, Pollution Control Branch, Ontario Ministry of the Environment.

The Reference Group established a number of committees and work groups. When the Reference Group submitted its report to the Commission, the committees and work groups consisted of the following members:

COORDINATING COMMITTEE

UNITED STATES MEMBERS

N. A. Thomas, U.S. Environmental Protection Agency, Co-Chairman.
K. E. Bremer, U.S. Environmental Protection Agency.
A. G. Kizlauskas, U.S. Environmental Protection Agency.
W. E. McCracken, Michigan Department of Natural Resources.
E. Pinkstaff, U.S. Environmental Protection Agency.

CANADIAN MEMBERS

S. E. Salbach, Ontario Ministry of the Environment, Co-Chairman.
J. P. H. Batteke, Canada Department of the Environment.
F. C. Elder, Canada Department of the Environment.
G. L. Van Fleet, Ontario Ministry of the Environment.
J. W. Schmidt, Canada Department of the Environment.

WORK GROUP A

UNITED STATES MEMBERS

E. Pinkstaff, U.S. Environmental Protection Agency, Co-Chairman.
P. E. Davis, Minnesota Pollution Control Agency.
D. Johnson, Michigan Department of Natural Resources.
R. Oghalai, Wisconsin Department of Natural Resources.

CANADIAN MEMBERS

J. P. H. Batteke, Canada Department of the Environment, Co-Chairman.
A. H. Lawrie, Ontario Ministry of Natural Resources.
R. C. Ostry, Ontario Ministry of the Environment.
D. W. Phillips, Canada Department of the Environment.
D. Pirie, Ontario Ministry of the Environment.
P. Yee, Canada Department of the Environment.

WORK GROUP B

UNITED STATES MEMBERS

A. G. Kizlauskas, U.S. Environmental Protection Agency, Co-Chairman.
J. K. Crawford, U.S. Environmental Protection Agency.

T. T. Davies, U.S. Environmental Protection Agency.
C. V. Marion, U.S. Environmental Protection Agency.
A. P. Pinsak, National Oceanic and Atmospheric Administration.
J. Saylor, National Oceanic and Atmospheric Administration.
W. A. Willford, U.S. Fish and Wildlife Service.

CANADIAN MEMBERS

F. C. Elder, Canada Department of the Environment, Co-Chairman.
E. B. Bennett, Canada Department of the Environment.
J. D. Kinkead, Ontario Ministry of the Environment.
A. H. Lawrie, Ontario Ministry of Natural Resources.
V. E. Niemela, Canada Department of the Environment.
M. D. Palmer, Ontario Ministry of the Environment.
K. Patalas, Canada Department of the Environment.
S. S. Rao, Canada Department of the Environment.
W. M. J. Strachan, Canada Department of the Environment.
R. L. Thomas, Canada Department of the Environment.
N. D. Warry, Canada Department of the Environment.
N. Watson, Canada Department of the Environment.

WORK GROUP C

UNITED STATES MEMBERS

W. E. McCracken, Michigan Department of Natural Resources, Co-Chairman.
S. Buda, Michigan Department of Natural Resources.
M. D. Mullin, U.S. Environmental Protection Agency.
L. R. Peissig, Minnesota Pollution Control Agency.
F. H. Schraufnagel, Wisconsin Department of Natural Resources.
D. Swanson, Michigan Department of Natural Resources.

CANADIAN MEMBERS

G. L. Van Fleet, Ontario Ministry of the Environment, Co-Chairman.
J. Archer, Ontario Ministry of the Environment.
F. C. Elder, Canada Department of the Environment.
S. Monroe, Canada Department of the Environment.
I. Ramsay, Ontario Ministry of the Environment.
R. A. Ryder, Ontario Ministry of Natural Resources.
L. Shenfeld, Ontario Ministry of the Environment.
M. Shiomi, Canada Department of the Environment.
D. Terry, Ontario Ministry of the Environment.
D. M. Whelpdale, Canada Department of the Environment.

WORK GROUP D

UNITED STATES MEMBERS

N. A. Thomas, U.S. Environmental Protection Agency, Co-Chairman.
W. D. Johnson, U.S. Environmental Protection Agency.
S. J. Kleinert, Wisconsin Department of Natural Resources.
J. Pegors, Minnesota Pollution Control Agency.
J. Robinson, Michigan Department of Natural Resources.

CANADIAN MEMBERS

S. E. Salbach, Ontario Ministry of the Environment, Co-Chairman.
M. G. Johnson, Canada Department of the Environment.
J. D. Kinkead, Ontario Ministry of the Environment.
V. E. Niemela, Canada Department of the Environment.
J. A. Reckahn, Ontario Ministry of Natural Resources.

COMMITTEE FOR DATA QUALITY

UNITED STATES MEMBERS

D. A. Payne, U.S. Environmental Protection Agency, Chairman.
D. J. Dube, Wisconsin Department of Natural Resources.
R. E. Frazier, Minnesota Department of Health.
J. M. Malczyk, National Oceanic and Atmospheric Administration.
M. D. Mullin, U.S. Environmental Protection Agency.
J. H. Peck, Michigan Department of Natural Resources.
M. S. Simmons, University of Michigan.

CANADIAN MEMBERS

K. I. Aspila, Canada Department of the Environment.
F. P. Dieken, Ontario Ministry of the Environment.
D. E. King, Ontario Ministry of the Environment.
F. J. Philbert, Canada Department of the Environment.

APPENDIX C

Persons Presenting Briefs or Testimony at the Commission's Public Hearings on the Upper Lakes Reference

December 5, 1972 at Thunder Bay, Ontario

Agnes Wilson for the Anti-Pollution Group of the Lakehead
Lori Chaboyer and Crystal Matchett for their class at Algonquin School
Ted Major, Magnavox Company
Carl Rose
Roger Pinkonski for the Northwestern Ontario Conservation Federation
Norman Richard for the Sudbury and Thunder Bay District Council, Ontario Federation of Labour
Jean Paul St. Jacques
Clifford Wahl for the Northwestern Ontario Communist Party
Robert Costello, Abitibi Paper Company Ltd.
Gordon Allen, Great Lakes Paper Company
Ed Fride, Reserve Mining Company
Miss Copps
Richard Martin for the Damn the Dams Campaign
W. D. Addison
J. David Bates
Peter Globensky
David Caverly, Ontario Ministry of the Environment
Dr. Ellis, Canadian Forestry Service
Sydney Pettit
P. Stennett
John Poleschuk for the Great Lakes Athletic Association Conservation Club
Thunder Bay Field Naturalists Club
C. Kastan

December 7, 1972 at Duluth, Minnesota

Philip A. Hart, United States Senate
Philip E. Ruppe, United States House of Representatives
Robert Peterson for the Minnesota State Community Action Program Council, United Auto Workers
Arlene Lehto for the Save Lake Superior Association
Martha Reynolds for the West Michigan Environmental Action Council
Soo Ecology Club
Mrs. Kenneth Wiele for the Range Wilderness League and the Northern Michigan Wilderness Coalition
Philip Doepke for Northern Michigan University and for Citizens to Save the Superior Shoreline
Steve Rose for the Community Action Program Council of Delta County, United Auto Workers
Kenneth Rathje for the Michigan United Auto Workers Community Action Program Council
Mr. Stoddard for the Northern Environmental Council
Wayne Johnson, Attorney for the Village of Silver Bay and for the Village of Beaver Bay

Lovell Richie, Minnesota Pollution Control Agency
Bruce Wallace, U.S. Army, Corps of Engineers
Gene Roach for Local 5296, United Steel Workers
Ed Fride, Reserve Mining Company
Francis Mayo, U.S. Environmental Protection Agency
William Steggles, Ontario Ministry of the Environment

January 8, 1973 at Bay City, Michigan

Gary E. Guenther, Michigan Water Resources Commission
Jim Dooley, Michigan Water Resources Commission
Pearl C. Servais
Willard Ashmore, Saginaw-Midland Water Supply System
Ezra Monroe, Saginaw Valley College
Conrad O. Kleveno, U.S. Environmental Protection Agency
Robert K. Lane, Canada Centre for Inland Waters

January 22, 1973 at Sault Ste. Marie, Ontario

Allan A. Jackson for the Pollution Control Association of Ontario
R. E. Costello, Abitibi Paper Company
A. C. Ruggles, Algoma Health Unit
Donald R. Evans, City of Sault Ste. Marie, Ontario
David S. Caverly, Ontario Ministry of the Environment
Albert J. Smith

January 24, 1973 at London, Ontario

Peter Lewington for Save the Medway
David S. Caverly, Ontario Ministry of the Environment
J. Robinson, University of Western Ontario
R. W. Packer for Save the Medway
City of Sarnia

June 20-21, 1977 at Superior, Wisconsin

Gary Glass
William A. Swenson, University of Wisconsin - Superior
Aldon Lind for the Save Lake Superior Association
Karen Carlson for the Save Lake Superior Association
Betty Hetzel for the League of Women Voters, Superior

June 22, 1977 at Thunder Bay, Ontario

Roger Andrew
Mrs. McEwan
Richard Hiner
Ken Tilson for HOPE
T. Miyata for Hydroprobe
Norman Richard for the Thunder Bay and District Labour Council
Philip Hurcomb for the Dominion Marine Association
Robert Hamilton, Ontario Ministry of Natural Resources
L. Siebenmann for Hydroprobe

June 23, 1977 at Hougton, Michigan

Robert T. Brown
Grace Marie Knapp
Kenneth Kraft
Stephen Nordang, Michigan Technological University
Barbara Clark for the Upper Peninsula Environmental Coalition
Emil Groth for the Upper Peninsula Federation of Landowners
Donald L. Macalady for Citizens to Save the Superior Shoreline
Julia Tibbitts for Superior Public Rights, Inc.
C. K. Lawrence, Homestake Copper Company
Lynn Sandberg, Mead Publishing Paper Division
Robert R. Raisanen, Upper Peninsula Power Company
John Suffron, Copper Range Company

July 12, 1977 at Sault Ste. Marie, Ontario

James W. Arthur
N. H. Sloane
B. Rasaiah
Gale Gleason
W. Sarich for Air Probe
Peter Allen, Sault Ste. Marie Regional Conservation Authority
Donald Redmond, City of Sault Ste. Marie, Ontario
Clarence Dungey for the Sault Ste. Marie Labour Council

July 13, 1977 at Collingwood, Ontario

Ray Mickeviuus, Town of Wasaga Beach
Mary E. Graham
R. E. Murray for Great Lakes Tomorrow
John R. Poste for the Blue Mountain Club of the Bruce Trail Association
John P. Gorman

July 14, 1977 at Saginaw, Michigan

Wayne Schmidt for the Michigan United Conservation Clubs
Nicki Habeland for the League of Women Voters, Bay County
Scott E. Coleridge, FMC Corp.
Stacey L. Daniels, Dow Chemical Company
Jim Sygo, East Central Michigan Planning and Development Region

In addition to the above, several written statements were submitted through the mail, subsequent to the hearings, by individuals or on behalf of organizations.

APPENDIX D

RECOMMENDATIONS
UPPER LAKES REFERENCE GROUP

ENRICHMENT

CORRECTION OF EXISTING PROBLEMS (REFERENCE QUESTIONS 1, 2, AND 3)

The Reference Group recommends:

1. Michigan ensure that the point source remedial programs in the Saginaw Bay Basin are completed by December 1978, to reduce the annual phosphorus load by 600 t/a.

2. Wisconsin and Minnesota ensure that the point source remedial programs in the Duluth-Superior Harbor area are completed by December 1978, to reduce the annual phosphorus load by 160 t/a.

3. The condition of Saginaw Bay and of Duluth-Superior Harbor be re-examined upon implementation of the phosphorus removal programs to determine if additional load reductions are needed.

4. The identification and control of the sources of phosphorus contributing to the problems in the Goderich area.

5. Surveillance be maintained at Penetang Bay, Midland Bay, and Collingwood Harbour to determine whether improvements are occurring as expected or whether additional remedial programs are warranted.

NONDEGRADATION (REFERENCE QUESTION 4)

The Reference Group recommends:

6. The phosphorus concentration in all municipal and industrial discharges be reduced to 1.0 mg/L or less as soon as possible.

7. The allowable phosphorus content of all detergents be limited to not more than 0.5% phosphorus by weight.

8. All practicable measures be taken to reduce phosphorus loadings from land use and nonpoint sources.

PUBLIC HEALTH MICROBIOLOGY

The Reference Group recommends:

9. The jurisdictions undertake the necessary remedial programs to bring areas exhibiting bacteriological water quality degradation into compliance with the Water Quality Agreement objectives.

10. New microbiological objectives be established and standard measurement methods be developed.

METALS

The Reference Group recommends:

11. There be no increase allowed for inputs of any metals to the Upper Lakes.

12. Mercury discharges from the American Can of Canada, Ltd. chlor-alkali plant at Marathon be eliminated by December 1978 as scheduled, and any other sources identified in the future also be eliminated.

13. Remedial programs to reduce iron and zinc discharges from Algoma Steel Co. at Sault Ste. Marie, Ontario should be developed and implemented as soon as possible.

14. The metals input from atmospheric sources be quantified and the maximum possible reductions be made as soon as possible.

15. The Governments monitor the unexplained high arsenic content in Lake Huron chubs and take the necessary measures to prevent worsening conditions.

16. The Governments monitor the identified high metals content in sediments and in water, and take the necessary measures to prevent worsening conditions.

ORGANIC CONTAMINANTS

TOXIC ORGANICS

The Reference Group recommends:

17. A total ban on the manufacture, sale, transport, and use of PCB's, aldrin, dieldrin, and DDT and its derivatives.

18. That for lindane, chlorobenzene compounds, chlordane, octachlorostyrene, and other man-made organics such as halogenated hydrocarbons, an accelerated program be initiated to evaluate effects on human health and biota, to establish a better basis for criteria, and to develop remedial programs as needed. Until the effects are fully understood there should be no increased manufacture, use, or discharge of these compounds.

19. Environmental and health effects be fully evaluated before new organic compounds are produced, distributed, or used.

20. The Governments immediately implement programs to minimize pesticide use, as recommended in the Early Action Program Report of March 1974, prepared by the Pollution from Land Use Activities Reference Group.

TASTE AND ODOUR COMPOUNDS

The Reference Group recommends:

21. Appropriate remedial measures be taken to eliminate the remaining taste and odour problems at Thunder Bay, Marathon, Jackfish Bay, and the mouth of the Spanish River, caused by pulp and paper mills.

22. Governments ensure that the waste treatment facilities for Algoma Steel at Sault Ste. Marie, Ontario be completed as soon as possible to achieve the Agreement objective for phenolic substances.

23. Governments ensure that appropriate measures be taken at Sault Ste. Marie, Ontario to reduce the present phenolic discharges from the sewage collection and treatment facilities so as to achieve the Agreement objective for phenolic substances by December 1978.

ASBESTOS

The Reference Group recommends:

24. Reserve Mining Company immediately cease discharging tailings, which contain asbestiform fibres, to Lake Superior.

25. The erosion and further asbestos loading from the tailings delta at Silver Bay, Minnesota be minimized.

26. The Governments immediately establish a drinking water standard for asbestos.

27. The IJC develop and recommend to Governments a water quality objective for asbestos.

28. The Governments intensify their support of research on the effects of fibre size, shape, and concentration on the health of all biological forms in the Upper Lakes <u>especially man</u>.

29. That the surveillance program for Lake Superior include monitoring the changes in asbestos concentration subsequent to the cessation of the Reserve Mining Company discharge.

RADIOACTIVITY

The Reference Group recommends:

30. The adequacy of present programs be assessed and, if needed, additional abatement measures be implemented in the Elliot Lake area to achieve compliance with the Ontario drinking water criteria.

31. The jurisdictions initiate without delay the surveillance plan prepared by the Radioactivity Subcommittee and incorporated into the Great Lakes surveillance plan developed by the Surveillance Subcommittee, in order to ascertain that changes in radioactivity occur as predicted and that no localized increase in concentration occurs.

DREDGING

The Reference Group recommends:

32. The Governments act upon the recommendations of the International Working Group on the Abatement and Control of Pollution from Dredging Activities, leading to the development and adoption of compatible regulations for dredging and dredge spoil disposal that fully consider the short- and long-term effects.

VESSEL WASTES

The Reference Group recommends:

33. Existing and proposed vessel waste regulations be amended to prohibit discharges of personal wastes from all vessels into Lakes Huron and Superior or into any of its harbours or embayments. Major ports should be required to provide adequate pumpout facilities for personal wastes.

34. All ocean vessels inbound to the Great Lakes be required to exchange seawater ballast for acceptable freshwater ballast prior to entering the Saint Lawrence Seaway.

35. Compatible regulations be developed and appropriate remedial programs be instituted to abate operational and functional waste discharges. Particular attention should be given to ocean-going vessels, self-loading/unloading vessels, and tankers.

SPILLS

The Reference Group recommends:

36. The regulatory agencies conduct post-spill studies to determine the associated long-term environmental effects of spills and cleanup.

37. As a result of these studies, improvements should be made in response measures and recovery technology.

38. The information base regarding the nature and the character of the material spilled be upgraded and reported in a common format.

THERMAL

The Reference Group recommends:

39. Comprehensive environmental assessment studies be conducted for each thermal discharger to be sited on the Upper Lakes with particular emphasis given to the design of intake and discharge structures to minimize fish and fish larvae entrainment.

ATMOSPHERIC INPUTS

The Reference Group recommends:

40. The Governments include phosphorus as an air pollution control parameter and determine its sources.

41. A surveillance program for atmospheric loading to the Upper Lakes, including synthetic organics, arsenic, and mercury, be instituted.

WATER QUALITY AGREEMENT OBJECTIVES

The Reference Group recommends:

42. The IJC continue to review all the criteria, standards, and objectives presently used and, where necessary, refine the present objectives and develop new specific objectives for inclusion in the Water Quality Agreement; and where less stringent criteria are in force, recommend the adoption of criteria at least as stringent as the objectives in the Agreement.

APPENDIX E

METRIC TERMINOLOGY AND CONVERSION FACTORS

This report employs the Systeme International d'Unites or "metric system". The SI units and their English equivalents are given below.

SYMBOL	NAME	EQUIVALENT		
g	gram			
kg	kilogram	1 kg	=	10^3g = 2.205 pounds
mg	milligram	1 mg	=	10^{-3}g
μg	microgram	1 μg	=	10^{-6}g
ng	nanogram	1 ng	=	10^{-9}g
t	tonne	1 t	=	1000 kg = 2205 pounds
d	day			
a	year			
L	litre	1 L	=	0.2200 Canadian gallons
			=	0.2642 U.S. gallons
m^3/s	cubic metres per second	1 m^3/s	=	35.31 cubic feet per second
			=	19.01 million Canadian gallons per day
			=	22.82 million U.S. gallons per day
pCi	picocurie	1 pCi	=	0.037 nuclear disintegrations per second

Signed this 30th day of May 1979 as the International Joint Commission's report to the Governments of the United States and Canada on the Water Quality of the Upper Great Lakes.

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